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OFFICE OF
CHEMICAL SAFETY AND
POLLUTION PREVENTION

Summary of New Information and Analysis of Dicamba Use on Dicamba-Tolerant (DT) Cotton and Soybean Including Updated Effects Determinations for Federally Listed Threatened and Endangered Species

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1. Description of the Federal Action

In 2016, EPA issued a dicamba time-limited registration to Monsanto (now Bayer[1]) for use on dicamba-tolerant soybean and cotton. The expiration on the 2016 registration is November 9, 2018. EPA received a request to amend this registration that included extending the registration to December 2020, as well as other labeling restrictions, as requested by EPA, to further minimize the potential for off-site movement of dicamba. In addition to the retention of the 110-foot downwind spray drift buffer currently on the Engenia, FeXapan and Xtendimax labels, which was an important component of earlier no effect determinations, additional label language and mitigations have been added to reduce the off-field movement of dicamba residues. These include the following changes from previous labels:

1. Restriction for use by certified applicators only (intended to increase label compliance).
2. Require dicamba specific training for all applicators (intended to increase label compliance).
3. Label language revision to improve label consistency and enforceability (intended to increase label compliance).
4. Revised language limiting dicamba application to an interval between 1 hour after sunrise and 2 hours before sunset (intended to reduce the potential for applications proximal to temperature inversion conditions).
5. Establishing the period of application limited to 45 days after soybean planting (or before R1 stage) and 60 days after cotton planting, with a maximum of 2 post-emergent applications (intended to reduce the frequency of events that could potentially result in off-site movement).
6. Tank clean out instructions to include clean out of the entire application equipment (intended to reduce the potential for cross-contamination).
7. Improve label description of sensitive crop/susceptible crop and sensitive areas (intended to improve label compliance and reduce the potential for dicamba application near sensitive non-target plants).
8. Enhance the label with pH advisory language to improve applicator awareness of the impact of low tank-mix pH on volatility of dicamba (expected to reduce the contribution of volatile dicamba to overall off-site exposure).

The above general label requirements are reasonably expected to improve pesticide applicator awareness of the potential for off-site dicamba movement and to further minimize dicamba movement potential. Additionally, all other previous label restrictions (*e.g.* nozzle restrictions, 110-ft downwind spray drift buffer, tank mix partner prohibitions etc.) remain in place.

[1] Fexapan and Engenia were registered after the Xtendimax Registration

The above list of label restrictions does not include any **additional** proposed mitigation to avoid effects to listed species. The effects determination in **Section 5** of this document, presents conclusions with and without mitigations in place.

The end-use products related to this decision are EPA Reg Nos. 524-617 (M1768 Herbicide, Xtendimax with VaporGrip Technology; Bayer CropScience, previously Monsanto Company), 7969-345 (Engenia Herbicide; BASF Corporation), and 352-913 (FeXapan Herbicide; Corteva Agriscience, previously Dupont).

This memorandum and effects determinations are for the 34 states that are currently registered for the dicamba over-the-top use pattern, as listed below:

> Alabama, Arizona, Arkansas, Colorado, Delaware, Florida, Georgia, Illinois, Iowa, Indiana, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, West Virginia and Wisconsin

2. Existing effects determinations

2.1. Previous Screening Level and Refined Ecological Risk Assessment Conclusions

In March 2016, EPA issued a Section 3 screening-level risk assessment for the use of diglycolamine salt of dicamba (dicamba DGA) on dicamba herbicide-tolerant cotton (USEPA, 2016a; D404823) and an addendum to the 2011 Section 3 screening-level Risk Assessment for the use of dicamba DGA on dicamba herbicide-tolerant soybeans (USEPA, 2016b; D426789). Concurrent with these two actions, EPA issued three addenda to the risk assessments (USEPA, 2016c-e; D416416+) that refined the screening-level risk assessments to include species-specific assessments for threatened and endangered (hereafter referred to as "listed") species present within the 34 states included in the Section 3 registrations on dicamba-tolerant crops (Alabama, Arizona, Arkansas, Colorado, Delaware, Florida, Georgia, Illinois, Iowa, Indiana, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, West Virginia and Wisconsin).

The screening-level risk assessments concluded that potential direct risk concerns <u>could not be excluded</u> for:

- mammals (chronic, from the soybean use only, due to residues from dicamba's metabolite, DCSA, rather than from parent dicamba);

- birds (acute from parent dicamba for both soybean and cotton uses; chronic from DCSA residues only in soybean but not in cotton), considered surrogates for reptiles, and terrestrial-phase amphibians; and
- terrestrial plants (soybean and cotton uses)

In the screening-level risk assessments, indirect effect risk concerns for all taxa <u>were possible</u> for any species that have dependencies (e.g., food, shelter, and habitat) on mammals, birds, reptiles, terrestrial-phase amphibians, or terrestrial plants.

Additionally, the screening-level assessment showed that direct risk levels of concern were not exceeded for:

- mammals (acute) and (chronic—for the cotton use only);
- birds, reptiles, and terrestrial-phase amphibians (chronic from parent dicamba or DCSA degradate from use on cotton);
- terrestrial insects (acute and chronic);
- freshwater fish (acute and chronic);
- aquatic-phase amphibians (acute and chronic);
- estuarine/marine fish (acute and chronic);
- freshwater invertebrates (acute and chronic); estuarine/marine invertebrates (acute and chronic); and
- aquatic plants[2]

In the screening-level cotton risk assessment and soybean addendum as part of the earlier public comment process, EPA concluded that mitigation measures, including the use of rainfast mitigation to limit runoff exposure, limiting nozzles to those that restrict droplet spectra to extra-coarse and ultra-coarse, restricting applications under certain wind conditions (*i.e.* only apply when wind speeds are between 3 and 15 mph), and the use of a 110-foot buffer (for a 0.5 lb a.i./A application) in the direction of wind to account for spray drift and applying that buffer in every direction to account for potential volatilization (a discussion of the updates to this assessment is provided below), would limit any exposures beyond the treated field to levels below thresholds that would trigger any risk concerns for any taxa. These assessments concluded that by applying the rainfast mitigation and utilizing the spray drift and volatility buffer as setbacks from the edge of the field ("in-field buffers"), exposures that could potentially trigger risk concerns would be limited to the treated field. With these labeling restrictions, EPA determined that the vast majority of listed species would be off-field and therefore would not be part of the action area and consequently reached a No Effect decision for those species. Species that were potentially on the treated field or utilizing resources from

[2] The listed species LOC was exceeded for non-vascular aquatic plants; however, there are no listed species in this taxa.

the treated field and for which the screening-level risk assessment indicated concerns for that taxa underwent further refinement to determine the potential for risk.

Subsequent to the screening level risk assessments and refined endangered species addenda, EPA issued several additional addenda including the evaluation of field volatility (flux) studies for DGA formulations (USEPA, 2016f; D435792), bridging data and volatility analysis for dicamba BAPMA salt (USEPA, 2016g-h; D402518, D436905) and an additional refined endangered species addendum (USEPA, 2016i; D436602) that covered listed species that were newly listed between the Section 3 registrations of dicamba DGA salt on dicamba-tolerant soybeans and cotton and the Section 3 registration of dicamba BAPMA salt. The evaluation of the flux studies for DGA and the volatility analysis for both DGA and BAPMA concluded that volatility buffer setbacks were not needed to limit exposures off the field to below the threshold level (set by the listed species endpoint for the most sensitive plant species tested, soybean), though uncertainties were noted at that time including whether the submitted flux studies (MRIDs 49888401, 49888403, 49888501 & 49888503) adequately encompassed the extremes of conditions (*i.e.* when temperatures are greater than the low 90^0s) that can increase the rate of volatility and the statistical uncertainty in the calculation of the risk quotient based upon the large 30x difference between the submitted vapor phase humidome NOAEC and LOAEC (MRID 49925703).

By limiting the action area to the treated field, the refined endangered species addenda (USEPA, 2016c-e, i; D416416+) concluded that all but 27 listed species were outside of the action area. Overall, of the remaining 27 species, one likely to adversely affect (LAA) determination was made, two not likely to adversely affect (NLAA) determinations were made, and no effect (NE) determinations were made for the remaining species (**Table 1**, reprinted from USEPA, 2016i; D436602).

Table 1. Summary of Previous Effects Determinations for Federally Listed Threatened or Endangered Species within the Action Area (USEPA, 2016i; D436602)

Species	Effects determination	Crops Pertinent to Effects Determination*	Areas of Concern
Indiana bat	NE	Cotton, Soybean	NA
Lesser long-nosed bat	NE	Cotton, Soybean	NA
Mexican long-nosed bat	NE	Cotton, Soybean	NA
Northern long-eared bat	NE	Cotton, Soybean	NA
Ozark Bat	NE	Cotton, Soybean	NA
Virginia big-eared bat	NE	Cotton, Soybean	NA
Canada Lynx	NE	Cotton, Soybean	NA
Gray wolf	NE	Cotton, Soybean	NA

Species	Effects determination	Crops Pertinent to Effects Determination*	Areas of Concern
Mexican wolf	NE	Cotton, Soybean	NA
Red wolf	NE	Cotton, Soybean	NA
Jaguar	NE	Cotton, Soybean	NA
Gulf-Coast jaguarundi	NE	Cotton, Soybean	NA
Ocelot	NE	Cotton, Soybean	NA
Sonoran pronghorn antelope	NE	Cotton, Soybean	NA
Whooping crane	NE	Cotton, Soybean	NA
Attwater's greater prairie-chicken	NE	Cotton, Soybean	NA
Eskimo curlew	NLAA	NA	NA
Gunnison Sage Grouse	NE	Cotton, Soybean	NA
Mississippi Sandhill crane	NE	Cotton, Soybean	NA
Audubon's Crested Caracara	NLAA	Cotton	Palm Beach County in Florida
	NE	Soybean	NA
California condor	NE	Cotton, Soybean	NA
Eastern Massasauga rattlesnake	NE	Cotton, Soybean	NA
Indigo snake	NE	Cotton, Soybean	NA
Gopher tortoise	NE	Cotton, Soybean	NA
Houston toad	NE	Cotton, Soybean	NA
American burying beetle	NE	Cotton, Soybean	NA
Spring Creek bladderpod	LAA	Cotton, Soybean	Wilson County in Tennessee
NA – Not Applicable as a No Effect determination has been reached or consultation has been concluded NE-No Effect NLAA- May Effect, Not Likely to Adversely Affect LAA- May Effect, Likely to Adversely Affect			

Species	Effects determination	Crops Pertinent to Effects Determination*	Areas of Concern
*Considering soybeans and cotton, which are the focus of the previous assessments and this addendum.			

For the Eskimo curlew, EPA consulted with U.S. Fish and Wildlife Service and they concurred with the NLAA Effects Determination, and no further action was needed for this species (USEPA, 2016d-e).

The XtendiMax™ With VaporGrip™ Technology (EPA Reg. No. 524-617) product label included the following language:

> "XtendiMax™ With VaporGrip™ Technology is approved by U.S. EPA to be used in the following states, subject to county restriction as noted: Alabama, Arkansas, Arizona, Colorado, Delaware, Florida (excluding Palm Beach County), Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Ohio, Pennsylvania, South Carolina, South Dakota, Tennessee (excluding Wilson County), Texas, Virginia, West Virginia, Wisconsin."

The Engenia™ (7969-345) and FeXapan™ herbicide plus VaporGrip™ Technology (352-913) product labels contain identical county restrictions.

Based on the county prohibitions described above, these restrictions addressed the other NLAA and LAA determinations for the Audubon's caracara and the Spring Creek bladderpod, respectively. Therefore, these species were no longer inside the action area of the dicamba uses on cotton and soybean. Consequently, **no** Effects Determination were needed because they would have resulted in an ultimate conclusion of **No Effect**.

2.2. Re-consideration of listed species

The documentation leading to initial effects determinations in 2016, using the best available information of the time, concluded that, with selected mitigations in place, concern for listed species effects from uses of Xtendimax DGA salt (Monsanto, Reg No. 524-617) and Engenia BAPMA salt (BASF, Reg No. 7969-345) on genetically modified (GMO) dicamba-tolerant (DT) cotton and soybean fields was limited to the confines of the treated fields themselves (*i.e.* the action area was the treated fields; USEPA, 2016c-e,i; DP Barcodes 40138, 404806, 404823, 410802, 411382, 416416, 420160, 420159, 420352, 420518, 421434, 421723, 422305, 425049, 426789, 432752, 435892, 436602, 436905).

New information that is now available [FIFRA 6(a)(2) reporting, state agricultural lead agency and news reports] appears to show that dicamba emissions (through spray drift, volatile drift, or a combination) from Xtendimax- or Engenia-treated GMO cotton and soybean fields may have resulted in effects to non-target terrestrial plants offsite from the treated fields. This new information demonstrates the need to reevaluate the 2016 Endangered Species Act (ESA) effects determinations involving Federally listed threatened or endangered terrestrial plants for any new regulatory decision involving the use of Xtendimax or Engenia on GMO cotton and soybean fields. Specifically, the action areas (the areas where effects are reasonably expected to occur) may be larger than estimated with earlier datasets, encompassing more geographic areas, and so increasing the potential for overlap with identified locations of listed terrestrial plant species.

The purpose of this addendum is to review new information and to review which, if any, species that were not identified in the previous effects determinations as being within the action area (the treated field), could now potentially be located within an expanded action area. The conclusions from the previous listed species effects determinations made in the initial screening level risk assessments and the refined endangered species addenda (USEPA, 2016c-e, j; D416416+) are maintained for all taxa except listed non-monocot plants that may exist near the treated field, where levels of exposure could potentially result in effects and any newly listed species of terrestrial animals that may be present on the treated field that were not previously assessed. The action area has been set considering the established most sensitive tested plant, soybean, a dicot plant. The available terrestrial plant data set indicates that the dicot plant species are generally more sensitive than monocots, and that the most sensitive tested dicot, soybean, is substantially more sensitive than the most sensitive tested monocot, onion (DP Barcode 378444). Comparisons with other potentially sensitive taxa (*e.g.* aquatic plants), also indicate that the soybean endpoints (the most sensitive tested species) are highly protective (USEPA, 2016b, D426789, Appendix D). There are no incident information or other data available to suggest the potential for direct effects to other taxa except for non-monocot plants. Given the already protective nature of the existing 110-foot wind directional in-field buffers for monocots, and the far lower sensitivity of the most sensitive monocots compared to the most sensitive dicots (most sensitive tested monocot, onion, is four orders of magnitude less sensitive than the most sensitive dicot, with an IC_{25} close to the field application rate; USEPA 2011; DP Barcode 378444), it is reasonable to exclude listed monocot plants and listed animal species from further effects determination efforts because all the available evidence suggests exposure off treated fields will be insufficient to trigger monocot or other listed animal taxa concerns.

3. Establishing Direct Effects Endpoints

3.1 EPA's use of Apical Endpoints in Risk Assessment

To assess the effects on aquatic and terrestrial organisms exposed to a chemical stressor, the Agency evaluates the available ecotoxicological literature to determine effects directly relating to an organism's fitness in the environment (*i.e.* apical effects based on effects reducing an organisms' survival, reproductive capacity and/or physiological growth; USEPA, 2004). These effects are based on direct inhibitions of an organism's ability to survive, reproduce, or grow. In the case of terrestrial plants, effects determinations center on plant height and weight (growth) that have meaning in the context of survival and reproductive potential of species in the environment. Plant growth endpoints (*e.g.* height and weight) address the ability of plants to competitively exclude other plants' demands on resources, thereby enhancing survival, and achieving sufficient growth to obtain adequate resources for the increased energetic needs for reproduction. The previous issued effects determinations for listed species following the use of dicamba on dicamba tolerant (DT) crops (USEPA, 2016c-e, j; D416416+) have been based on the observed most sensitive effects to apical endpoints reported in the available suite of ecotoxicological data. More specific information on endpoints used in previous risk assessments is described below in **Sections 3.5** (toxicity endpoints used in comparisons with spray drift exposures) and **Section 4.2** (toxicity endpoints used in comparisons with from vapor drift exposures).

3.2 Consideration of Previous Field Study Data

Many new and previously published field studies of dicamba investigating plant effects are based on measures of visual damage, height, or crop yield (seed mass produced). Anecdotal reports of off-site injury (primarily as visual signs of injury) suggest potential movement of dicamba at levels causing observable plant responses to dicamba exposures (AAPCO, 2017, 2018). These lines of evidence have caused us to reexamine our earlier determinations based on the previously submitted registrant studies, that dicamba exposures above threshold levels of concern remain confined to the treated field. Additional newly submitted flux and humidome data (described below in **Sections 4.1** and **4.2**) generally support the previous effects determinations that volatile drift alone would not reach levels that would trigger concerns for non-target plants, based on previously used modeling methodologies. In coming to the conclusion that under the 2017 terms of registration there is potential for dicamba exposures outside the treated field that are sufficient to cause effects to listed plant species, EPA considered additional lines of evidence that would assist in resolving the conflict between reported incidents, mass emissions, and the extent of the action area used for effects determinations (the area where effects are expected to occur). Quantitative incorporation of additional lines of information (such as new field study data), as discussed below, resulted in a revised action area for over-the-top use of dicamba DGA and dicamba BAPMA salts on DT cotton and soybeans. This approach is consistent with previous approaches in which field data were incorporated in the ecological risk assessments and effects determinations as lines of evidence to support the 110 foot in-field buffer in the direction of wind to decrease off-field exposures from spray drift below toxicity thresholds. Similarly, field data were also used in the previous effects determinations and addenda to the ecological risk assessments as lines of evidence that edge of field concentrations from volatility were below toxicity thresholds, supporting the previous conclusion that omnidirectional buffers around the field were not needed to restrict the action area.

This updated assessment reevaluates whether a new action area is necessary. This new determination is limited to the taxa and types of exposures suggested by the new information available in incident reporting from FIFRA 6(a)(2) documents, state reports, and meetings with stakeholders. These incidents involve direct toxic effects to non-target plants from reported alleged off-site exposure to dicamba from spray drift, volatile drift, or a combination of both.

While the available incident data suggests potential effects beyond the treated field can damage non-target plants, the available information is insufficient to precisely determine the distance from treatment sites over which effects are observed, given the lack of quantitative measurements regarding impacts to plant height, yield or survival described in the incident reports.

3.3 Field Studies in the context of effects to listed plant species

To evaluate the potential for effects to listed plant species, EPA typically uses measurements of apical endpoints (*e.g.* plant height) from laboratory studies conducted under conservative conditions that ensure exposure at measured doses as opposed to field studies that test phytotoxic effects under more variable environmental conditions. From these studies, EPA uses the NOAEC (No Observed Adverse Effect Concentration) associated with the most sensitive species' EC_{25} value as the effect threshold to determine whether exposures are above the threshold level and consequently have the potential to cause risk to listed plant species. EPA also commonly calculates a regression estimate of the 5% effect level (EC_{05}) that is used in lieu of the NOAEC when a NOAEC cannot be determined from the study.

Many of the field studies of dicamba were not designed to capture a no-effect level (NOEL) for all measures of plant damage. Consistent with the EC_{05} growth endpoints typically used for effects determinations for listed species, based on guideline terrestrial plant studies when a NOEL is not reliably established, the Agency considered a 5% threshold interpolation (regression estimate when comparing distances or doses and biological effects) when evaluating the available field studies where effects on plant apical endpoints were measured.

3.4 Consideration of Field Measurement Data to Establish the Action Area

This effects determination considers the new and previously submitted field measurement data for soybean to establish the limit of the action areas. The available data include newly submitted field volatility (flux) studies (MRIDs 49899601, 49888603, 50578902, 50606801, and 50642801) and plant humidome data (MRID 50578901), both conducted to assess potential damage from vapor-phase exposures of dicamba and refine previously issued addenda assessing dicamba volatility exposure and effects (*e.g.* USEPA, 2016f; D435792).

To examine whether there was recent literature on potential impacts from volatility and/or spray drift of dicamba, EPA conducted a search for off-site transport and effects data through an on-line search of Google Scholar with the search terms: "dicamba" and any one of the following terms: "off-site transport", "volatility", "drift", and "non-target". EPA confined consideration of identified information to the years 2016-2018 since that time period presents the greatest opportunity to identify studies using the currently labeled Xtendimax and Engenia products. EPA also conducted a Google Scholar search with the terms "dicamba" combined with "visual signs of injury" and the term "height" or "yield". This latter search was used to inform analysis appearing in **Appendix A.** In addition, EPA considered additional field effects data submitted to the Agency in 2018 from independent researchers and the registrants. These studies are discussed in **Section 4.4**. A tabulation of the results from all the available field studies considered is in **Appendix B**.

3.5 Focus on Non-Monocot Plant Species

As discussed above, the available terrestrial plant data set indicates that the dicot plant species are generally more sensitive than monocots, and that the most sensitive dicot, soybean, is substantially more sensitive than the most sensitive monocot, onion (DP Barcode 378444). Given the already protective nature of the existing in-field buffers for spray drift (110 feet) for monocots, and the far lower sensitivity of the most sensitive monocots compared to the most sensitive dicots (most sensitive monocot, onion, is approximately three orders of magnitude less sensitive than the most sensitive dicot, soybean; based on equivalent endpoints (*e.g.* NOAEC/IC_{05}) used to assess potential risk to listed species of 0.072-0.137 and 0.000261-0.0003 lb ae/A, respectively for onions and soybean (MRIDs 47815102 and 48718015), it is reasonable to exclude listed monocot plants from further effects determination efforts because there is no evidence to suggest exposure off treated fields will be sufficient to trigger monocot concerns. Moreover, the initial screening level risk assessment on DT-soybeans (USEPA, 2011; D378444) demonstrates, even without in-field buffers, that off field movement was below the NOEC for the most sensitive monocot plants a scant 7 feet from the field edge with non-conservative drift estimates. This distance is within the margin of error for any overlap analysis and is essentially equivalent to only the treated field itself.

The vast majority of available field studies investigated the effects of dicamba exposure on non-dicamba tolerant soybeans. Based on a comparison of EC_{25} values across the standard suite of tested species, soybeans were determined to be the most sensitive species from the available laboratory toxicity assays (MRID 47815102 and 48718015 for dicamba DGA and BAPMA salt formulations, respectively). As such, they are utilized as a reliably representative species for evaluating potential effects to sensitive listed species. Additional field study data on other plant species were considered, where effects to apical endpoints were measured (*e.g.* Knezevic et al. 2018, discussed above).

4. Establishing the Distance from Treated Fields Where Plant Effects are Reasonably Expected to Occur

The previous effects determinations (USEPA, 2016c-e, j; D416416+) concluded that any potential effects following the use of registered dicamba products for over-the-top use on dicamba-tolerant plants would be limited to the treated field following the labeled mitigations to reduce spray drift (*e.g.* nozzles, wind speed restrictions) and the 110-foot spray drift buffer in the direction of wind at the time of application. Although the initial screening risk assessments (USEPA, 2016a-b) recommended the use of an omnidirectional buffer to preclude the potential for off-field dicamba exposures from volatility, further refinements based on submitted field flux data suggested that edge of field concentrations from vapor drift were expected to be below any thresholds of concern (USEPA, 2016f; D435792 and USEPA, 2016h; D402518 for DGA and BAPMA salts, respectively).

As discussed above, complaints of alleged dicamba damage of off-site injury from a variety of sources including investigative reports from multiple states since 2016 suggest that movement of dicamba could be occurring at levels causing plant injury (visual signs, damage to fruit, etc.). Comparative flux emissions from new field studies would suggest, in some cases for both Engenia and Xtendimax products, that total flux emissions are of sufficient mass to meet or exceed thresholds of non-target plant effects under conservative exposure assumptions (see **Sections 4.1 & 4.4**). These lines of evidence call into question our earlier determinations based on the previously submitted registrant studies and modeling methodologies, that dicamba exposures above threshold levels of concern remain confined to the treated field. However, newly submitted flux and humidome data (described below in **Sections 4.1** and **4.2**) generally support the previous effects determinations that demonstrated that any concentrations of vapor drift were expected to be below thresholds of concern. EPA considered additional lines of evidence that assisted in resolving the uncertainties that have arisen due to differences in the multiple lines of evidence in order to determine the appropriate action area for making effects determinations (the area where effects are expected to occur).

4.1 New Registrant-submitted Field Volatility (Flux) Data

Since the development of the risk assessment in November 2016 that determined omnidirectional buffers were not needed (USEPA, 2016f; DP Barcode 435792), four additional field volatility studies (OCSPP Guideline 835.8100) have been submitted to further characterize potential emissions coming from a dicamba-treated field. A comparison of the new emission rates (*i.e.*, flux rates) to those used in the November 2016 risk assessment is provided in **Figure 1**. The GA Clarity, TX Clarity, GA Xtendimax, and TX Xtendimax flux rates (based on MRIDs 49888401, 49888403, 49888501 & 49888503) were used in the November 2016 analyses. The Engenia flux rates are also provided for comparison purposes.

The remaining flux rates (GA Xtendimax+R [MRID 49888601], TX Xtendimax+R [MRID 49888603], TX MON 76980/MON79789 [MRID 50578902], Australia MON 76980/MON78789 [MRID 50606801], and AZ MON 76980/MON78789 [MRID 50642801]) are based on recently submitted field volatility studies, new since the 2016 assessment, and are briefly discussed below. While flux rates derived from the recent trials are higher than the rates derived for the other studies conducted at an application rate of 0.5 lb ae/A (the post-emergent over-the-top application rate), the flux rates are lower than those used in the 2016 assessment (which were based on 1 lb a.e./A, the highest allowable pre-emergent application rate). The modeled air concentrations and the atmospheric deposition amounts at the edge of the field for these recent studies are still below the effects endpoints (17.7 ng/m3 and 2.61×10^{-4} lb ae/A for vapor and spray droplet exposures, respectively) used in the 2016 assessment (USEPA, 2016f; D435792) that concluded omnidirectional buffers were not needed. Consequently, the new information from these field flux studies would not alter the effects determinations made in the

2016 assessments. The analysis made in 2016 evaluated exposure routes singularly and did not consider the combined exposure pathways of spray drift and volatility, an attribute reflected in some of the recently available field studies discussed below.

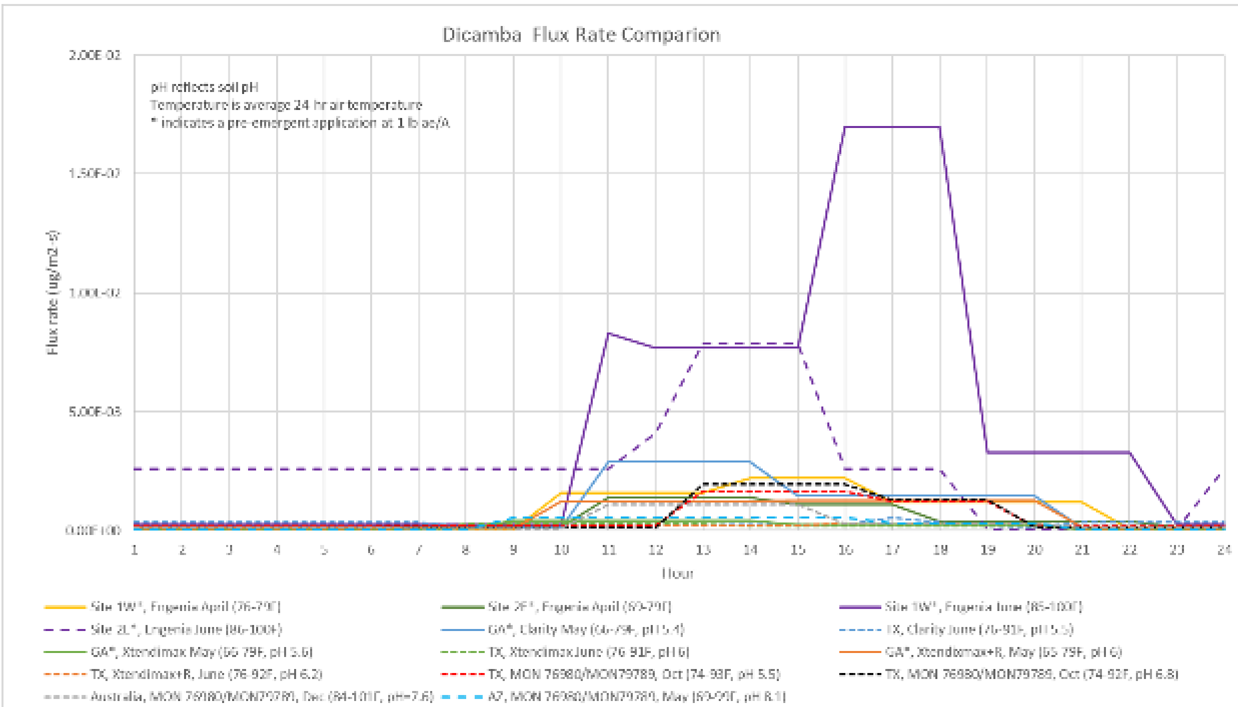

Figure 1. Comparison of Registrant Submitted Flux Studies for Dicamba Applications

In May and June 2015, field volatility studies were conducted in Chula, GA (MRID 49888601) and Kendleton, TX (MRID 49888603), submitted to EPA in 10/2016 as part of a different new product registration application. These studies are also informative for the currently registered OTT dicamba products. The test substances used in the field phase of these studies were MON 76832, a Roundup Xtend formulation (Xtendimax with VaporGrip and glyphosate) containing a mixture of dicamba DGA salt (120 g a.e./L) and glyphosate (242 g a.e./L). The plot dimensions were approximately 384 feet by 384 feet (3.4 A) in GA and 648 feet by 648 feet (9.6 A) in TX. The test plot at the GA site was a bare ground site treated at a rate of 1 lb a.e./A, while the TX site was a field of cotton, planted with a variety of Bollgard II® XtendFlexTM Cotton, treated at a rate of 0.5 lb a.e./A.

The cotton was at the 6-8 leaf stage and roughly 11 inches in height, at the time of dicamba application. The boom height for the spray application was set at 14-18 inches above the canopy or ground height. The spray application was made to the GA test plot at 9:00 am on May 5th, while the application to the TX plot was in the afternoon at 2:45 pm on June 8th. In GA temperatures during the first 24 hours ranged from 59-86°F and 60-91°F on Day 2. Relative humidity in GA ranged from 10-94% and soil pH was 6.0. In TX, temperatures during the first 24 hours ranged from 70-98°F and 72-97°F on Day 2. Relative humidity in TX ranged from 18-97% and soil pH was 6.2. The maximum 95th percentile 24-hour average concentrations from air modeling from PERFUM runs performed by the study authors were 3.2 and 16.1 ng/m^3 for the bare and cotton fields, respectively, at the edge of the field. The maximum 90th percentile 24-hour total deposition values from AERMOD runs performed by the study authors were 1.2x10^{-5} and 4.1x10^{-5} lb a.e./A for the bare and cotton fields, respectively, at the edge of the field.

In October 2016, a field volatility study was conducted in Fort Bend, TX (MRID 50578902, submitted to EPA 07/23/2018). The formulation, MON 76980 (which is not registered in the United States but is similar to Xtendimax plus VaporGrip), contains dicamba in the form of its DGA salt (42.8% by weight, 28.9% a.e.). MON 79789, which is glyphosate in the form of its potassium salt (48.7% by weight, 39.6% a.e.), similar to Roundup Powermax, was added with MON 76980 to the tank mix. The product was applied at an application rate of 0.5 lb a.e./A on October 4, 2016 at noon to two different types of agricultural field test plots:

1. a fallow (bare ground), 4.6-acre field and,
2. a 9.1-acre field planted with herbicide-tolerant cotton.

The bare ground plot was defined as having stubble less than 7.5 cm (approximately 3 inches) in height in the area of application and measurement. Spray application to the cotton test plot was representative of typical post-emergence herbicide applications to cotton (2-leaf stage or greater at time of application). The boom height for the spray application was set at 50.8 cm (20 inches) above the cotton crop (24-26 inches above the soil surface, indicating the cotton crop was 4-6 inches in height). Temperatures during the first 24 hours ranged from 70-94°F and 72-96°F on Day 2. Relative humidity during application was approximately 57-59%. Soil pH was 5.5 on the bare ground field and 6.8 on the cotton field. The maximum 95th percentile 24-hour average concentrations from air modeling PERFUM runs performed by the study authors were 15.6 and 12.6 ng/m^3 for the bare and cotton fields, respectively, at the edge of the field. The maximum 90th percentile 24-hour total deposition values from AERMOD runs performed by the study authors were 3.68x10^{-5} and 2.9x10^{-5} lb ae/A for the bare and cotton fields, respectively, at the edge of the field. EPA verified the concentration and deposition estimates derived by the study authors.

In December 2017, a field volatility study was conducted in Walgett Shire Australia (MRID 50606801, submitted to EPA 07/23/2018). The test substances used in the field phase of this study were MON 76980 and MON 79789. The formulation MON 76980 contains dicamba DGA salt (29.0% by weight, 28.9% a.e). The formulation MON 79789 contains glyphosate in the form of its potassium salt (39.8% by weight). In addition to the test substances, the tank mix contained Precision Laboratories Intact™ (Lot # PLB-1709-24800-I), a drift control and foliar retention agent and deposition aid, at a rate of 0.5% v/v. Intact™ contains polyethylene glycol, choline chloride, and guar gum as principal functioning agents that comprise 43.18% of the product. The plot dimensions were approximately 1280 feet in length and 1260 feet in width, for a total treated area of approximately 37 acres. The test plot and surrounding buffer zone was planted in a glyphosate, but not dicamba, tolerant variety of soybean. Soybean plants were roughly 6 inches in height. The boom height for the application was set at 24 inches above the soybean crop. The spray application was made to the test plot at 10:30 am on December 15,

2017. MON 76980 was applied at a target rate of 22 oz/A (0.5 lb a.e./A) and MON 79789 was applied at a target rate of 32 oz/A (1.125 lb a.i./A). Temperatures during the first 24 hours ranged from 76-106°F and 77-106°F on Day 2. Relative humidity during application was approximately 32%. Soil pH was 7.6. The maximum 95th percentile 24-hour average concentration from air modeling from PERFUM runs performed by the study authors was 4.4 ng/m^3 for the soybean field at the edge of the field. EPA verified the concentration and deposition estimates derived by the study authors. The maximum 90th percentile 24-hour total deposition value from AERMOD runs performed by the study authors was 2.68x10^{-5} lb a.e./A for the soybean field at the edge of the field. This study is classified as supplemental because flux rates for Day 2 could not be calculated due to high wind conditions. Originally the study included plant effects measurements in an attempt to differentiate plant injury due to spray drift versus volatility. However, prior to study initiation, the study area and the surrounding area were damaged by 2,4-D spray drift. Additionally, residual isoxaflutole was measured in the soil, confounding plant damage measurements. As a result, an assessment of plant damage surrounding the treated area was not included in the study.

In May 2018, a field volatility study was conducted in Maricopa, AZ (MRID 50642801, submitted to EPA 08/23/2018). Approximately 27 acres (1050 ft in length and 1120 ft wide), in the center of a 33-acre agricultural field planted with non-tolerant soybean, was treated with Xtendimax with VaporGrip, RoundUp PowerMax, and Intact on May 8, 2018 at 4:15 pm. The test plot and surrounding buffer zone were planted in non-tolerant soybean on April 3, 2018. Test substance applications were made using a John Deere 4630 ground sprayer equipped with an 80 ft boom and Turbo TeeJet® Induction (TTI) 11004 nozzles. A spray drift test system consisted of three downwind transects (east side of field) spaced approximately 15 m apart perpendicular to the spray area near the middle of the spray swaths. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all three transects at 5, 10, 15, 20, 25, and 30 m away from the field. Deposition collectors were mounted on metal posts elevated to the soybean crop height (15 cm). Three upwind (west side of field) collectors were located along the depositional transects 30 m from the upwind edge of the spray area, and three were located 40 m from the upwind edge of the spray area. A volatilization test system, including both in-field and off-field (perimeter) sampling locations as well as flux meteorological stations for the test plot, was also implemented. Lastly, a plant effects test system, including a uniform stand planted with soybeans tolerant to glyphosate, but not dicamba (non-dicamba tolerant soybeans), was implemented upwind and downwind of the treated areas. Plant effect transects were planted perpendicular to the eastern (downwind) and western (upwind) edge of the applied area to a maximum distance of 30 m (3 downwind pairs and 2 upwind pairs) to evaluate volatility and spray drift exposure. Plant effects from volatility were evaluated by covering approximately 30 m by 3 m of non-tolerant soybean crop along the volatility transects during the application period to prevent exposure via spray drift. The covers were removed approximately 30 minutes after application. Plants were measured before application (five sets of ten plants) from downwind, upwind and within the designated treated area to better characterize the inherent variability across the field. Control (untreated/no visual dicamba injury observed) plant height measurements (ten sets of ten plants) were collected non-systematically from areas further upwind of the upwind transects on the same day as plant height assessments. At each study transect, plant heights were measured 15 and 28 days after treatment (DAT; post-application) on ten plants at each distance along each transect distance (5, 10, 15, 20, 25 and 30 m).

The wind directions at the time of application were variable within and outside of the target, with an orientation of 267°. Wind directions and wind speeds during the daytime (8:00 am to 8 pm) and nighttime during conduct of the study are provided in **Figures 2** and **3**. Temperatures for three days after application ranged from 18.5 to 40.4°C (65 to 105°F) and relative humidity ranged from 8.3 to 38.9%. Flux rates were estimated using the integrated horizontal flux technique, the aerodynamic method, and the indirect method. On-field wind speed samplers malfunctioned during the first 27 hours of sampling, so study authors used data from an off-field station to estimate the wind speeds that would be expected at the on-field samplers. While the flux rates estimated using the integrated horizontal flux method and the aerodynamic flux method, which used these estimated wind speeds, during this time were not significantly different than those estimated using the indirect method, the flux rates using the indirect method were higher and were considered more reliable. These were the flux rates used in the air modeling as well, which yielded a maximum 95th percentile 24-hour average concentrations from PERFUM runs performed by the study author of 3.6 ng/m^3 for the soybean field at the edge of the field and a maximum 90th percentile 24-hour total deposition value from AERMOD runs performed by the study author of 1.00x10^{-6} lb a.e./A for the soybean field at the edge of the field. EPA verified the concentration and deposition estimates derived by the study authors.

Spray drift measurements indicated that dicamba residues were not detected in any of the upwind samples and were detected at levels below 24.5 µg/m^2 (2.19 x 10^{-4} lb/A). It should be noted that wind directions at the time of application were variable within and outside the target orientation of 267°. Additionally, samples were collected 3 minutes after applications were complete, which may not have been sufficient time for airborne droplets to deposit. As such, deposition values are considered uncertain.

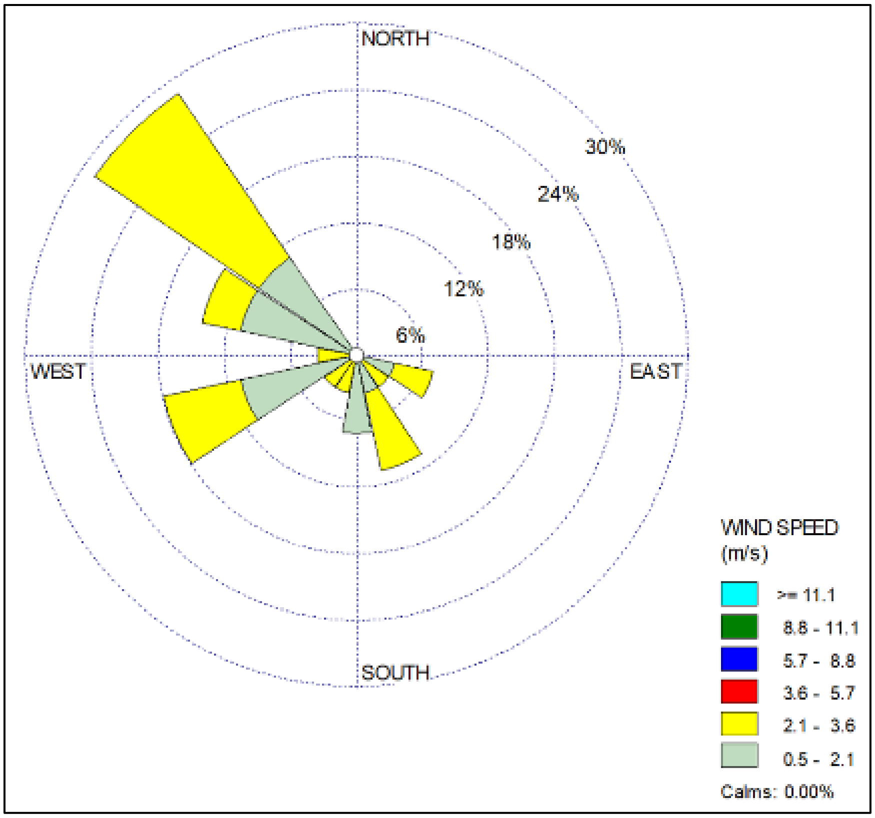

Figure 2. Wind Rose Plot, AZ Study, Daytime Hours

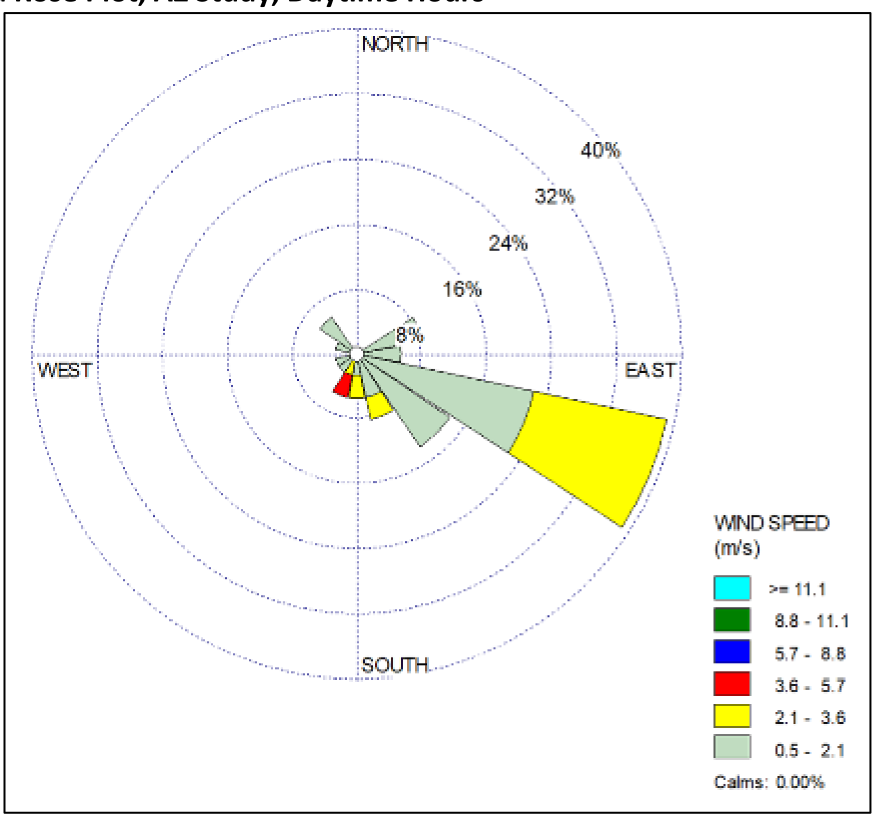

Figure 3. Wind Rose Plot, AZ Study, Nighttime Hours

Following 28 DAT, significant differences on plant height were observed between the downwind spray drift and volatility transects at 15 and 30 m; however, the study authors did not consider the differences treatment related as there was no clear dose response with respect to plant heights (**Figure 4**). For example, plant heights were significantly greater in the volatility transects at 15 m, whereas at 30 m plants were larger in the drift transects. Although attempts were taken to minimize variability, plant height differed across the field from the upwind to the downwind area (at Day 0, the average upwind plant height was 9.3 cm and the average downwind plant height was 7.64 cm). Therefore, due to the nonuniformity of plant height across the field, study authors did not perform a comparison of the plant height data to the upwind controls. At 28 DAT, no visual symptomology was reported in the downwind and upwind volatility transects off the treated field. Visual symptomology in the downwind spray drift transects was more pronounced compared to the downwind volatility transects. Visual symptomology in the spray drift transects decreased with increased distance from the treated area ranging from 30% at 5 m to a maximum of 5% at 30 m.

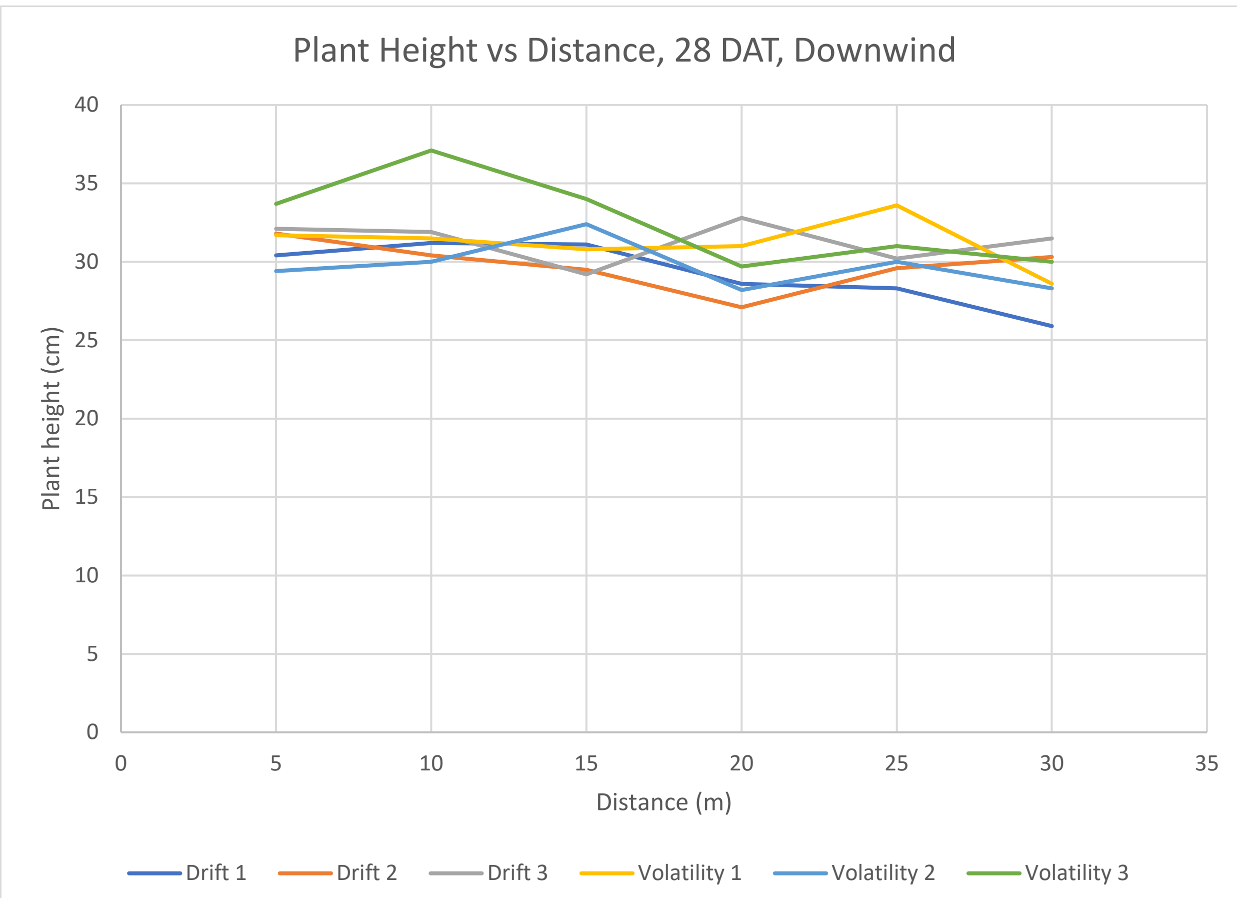

Figure 4. Plant Height Comparison, AZ Study

4.1.1 Placing all available flux studies into perspective

Using the results from the various field volatility studies, EPA examined the mass coming off the field in volatile form to determine if there was sufficient mass coming off the entire field to cause a concern from vapor drift exposure. To determine if this route could be excluded, EPA made a conservative assumption, for comparative purposes, that the available fugitive mass would be entirely deposited to a nearby field of the same dimensions (**Figure 5**). Because flux studies varied in application rate, it was necessary to normalize the resulting mass of dicamba leaving the treated fields to the labeled rate to 0.5 lb/A and the normalization process assumed that the total mass leaving the field linearly followed the change in application rate. While the assumptions made in this comparison are likely conservative, and do **not** accurately represent an aerial extent or distance down range over which effects might occur, the comparison does provide evidence that volatility remains an exposure route warranting further consideration.

Figure 5 suggests that a variety of field flux trials for Clarity, Engenia and Xtendimax produce enough field volatile emissions to trigger plant concerns, under a conservative assumption that mass emitted is subsequently deposited on an equivalent area of down range land. As noted above, this is based on conservative assumptions and not meant to be predictive of the actual expected adjacent field concentrations.

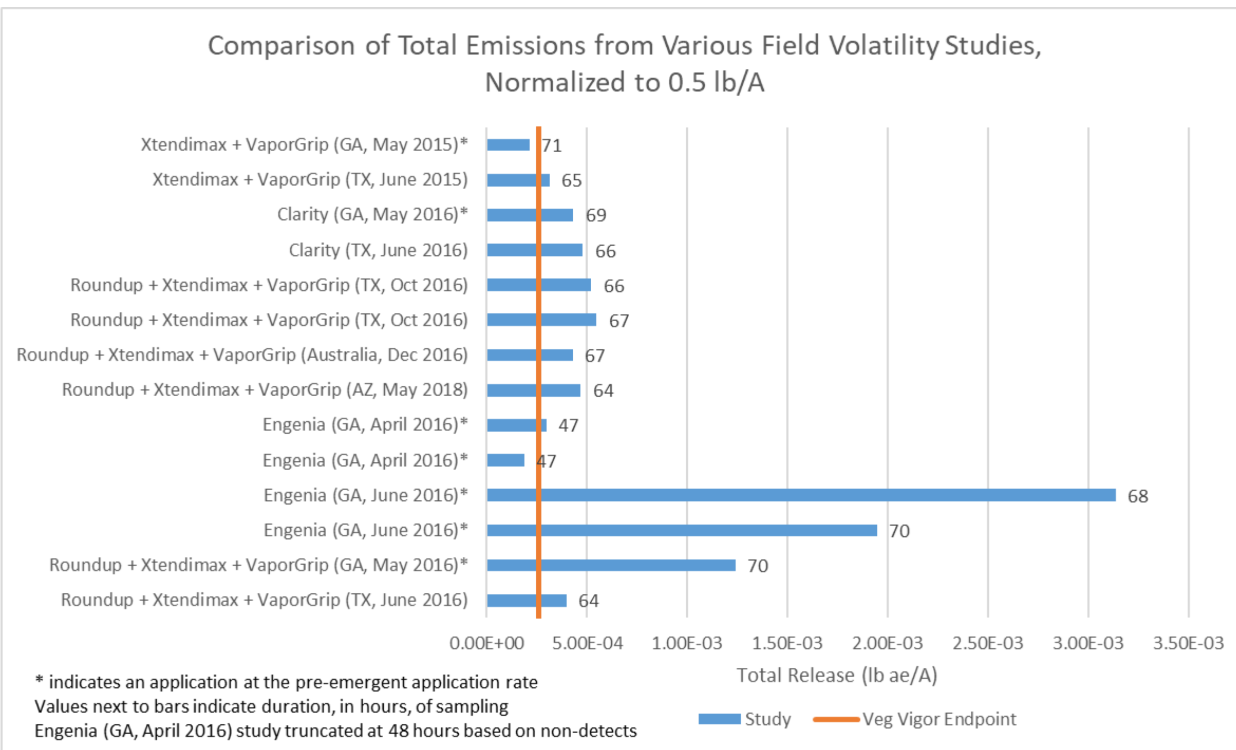

Figure 5. Comparisons of total emissions from various field volatility studies versus the listed species endpoint (0.00026 lb ae/A). All flux emissions are normalized to an application rate of 0.5 lb/A (labelled rate) and emissions are assumed to change linearly with application rate.

It should be noted that the studies were all conducted under varying field conditions and that a side-by-side comparison of Engenia releases and Xtendimax releases is not appropriate. The studies had variable meteorological conditions (*i.e.*, temperature and relative humidity), field conditions (*i.e.*, soil texture, temperature, moisture, and pH), and tank mix conditions (pH), all of which could increase or decrease the emissions from a treated field. The studies were designed to be done under real-world, conservative conditions with regards to temperature (*i.e.*, higher temperatures theoretically yielding higher emissions).

4.2 New Plant Humidome (Vapor Effects) Data

In EPA's 2016 assessment (USEPA, 2016f; DP Barcode 435792), EPA relied on a NOAEC of 17.7 ng/m^3 and a LOAEC of 539 ng/m^3 for vapor phase dicamba risk conclusions (MRID 49925703), but noted that "that the dose spacing in this study results in an approximately 30x difference between the NOAEC and LOAEC, creating uncertainty as to where effects to plants from vapor-phase exposure to dicamba may occur." Since the 2016 risk assessment was completed, a new study (MRID 50578901) has been submitted by a registrant to address this uncertainty. The explicit purpose of this study was "to examine the relationship between dicamba vapor concentration and plant response to identify a refined no observed effect concentration (NOEC) that can be used to support the risk assessment for dicamba use on dicamba-tolerant crops."

The biological results of this new study indicated that soybean height was not significantly reduced compared to control plants following 24 hours of exposure (at 85°F for 16 hours and 70°F for 8 hours with 40% relative humidity) to vapor-phase dicamba at concentrations less than or equal to 138 ng/m^3; however, 24-hour exposure (at 85°F for 16 hours and 70°F for 8 hours with 40% relative humidity) to concentrations of vapor-phase dicamba greater than or equal to 238 ng/m^3 significantly reduced soybean height (12%) compared to control plants ($p<0.0001$). As a result, EPA considers the new NOAEC to be 138 ng/m^3 (an approximate 8-fold increase relative to previous NOAEC), and the predicted peak air concentrations of 60.3 ng/m^3 and 20.8 ng/m^3 (for the Clarity and Xtendimax formulations, respectively) from the risk assessment would no longer exceed the NOAEC described in the 2016 addendum (USEPA, 2016f). Results from this new study fall within the range of the previous NOAEC and LOAEC endpoints, and with the refined dose spacing, there is greater certainty in the new NOAEC and LOAEC endpoints, compared to the previous vapor phase study. This new endpoint does not alter the previous effects determinations, though it does bolster the additional characterization of plant risks described in EPA's 2016 assessment and provides greater certainty surrounding the exposure levels necessary to result in damage to soybean apical endpoints from vapor exposure.

4.3 Studies Measuring Effects in the Field Evaluate the Combined Results of Multiple Routes of Exposure

As has been noted earlier in the document there are uncertainties as to why there are differences between previous risk assessment conclusions regarding the potential for off-site terrestrial plant effects and reported complaints of non-target plant response to dicamba exposure off-field. It should be noted that reliance on spray drift calculations for exposure and flux-based vapor drift estimates using field flux data, the PERFUM model and humidome studies have the potential to not fully account for the possible combined exposure of off-site plants to multiple routes of dicamba transport (*e.g.* combined spray drift and volatility exposures).

To provide additional actual field representation for this effects determination, EPA investigated available data (i.e., registrant-submitted studies, open literature, and academic studies) involving the response of plants in actual areas near treated crops. Having the additional line of evidence being field testing, EPA can more fully account for the potential for plants to be exposed to a combination of dicamba from spray drift and volatile drift.

A tabulation of the results from all the available studies considered is in **Appendix B** and descriptions of each study are provided in the following sections.

4.4 Available Recent Field Studies

To examine whether there was recent literature on potential impacts from volatility and/or spray drift of dicamba, EPA conducted a search for off-site transport and effects data through an on-line search of Google Scholar with the search terms: “dicamba” and any one of the following terms: “off-site transport”, “volatility”, “drift”, and “non-target”. EPA confined consideration of identified information to the years 2016-2018 since that time period presents the greatest opportunity to identify studies using the currently labeled Xtendimax and Engenia product. EPA also sought out any field study data that may have been conducted over the last two years (*e.g.* using the registered formulations for dicamba use on dicamba-tolerant soybean and cotton) through contacts at academic institutions, scientific associations and agricultural extension experts. A discussion of all the field studies evaluated in this document is available in **Appendices A** and **B**.

An important aspect of confidently establishing field effects thresholds for height or yield effects is to consider the sensitivity of height and yield measures with respect to growth stage of the tested plant species. While it is important to realize that this effects determination is using soybeans as a sensitive surrogate plant to represent other non-monocot plants with varied schedules for growth and reproduction, it is also important to understand the limits of the empirical designs of studies as they relate to growth stages of soybeans. Field effects studies with soybeans are typically conducted using plants in either vegetative growth stage or reproductive stage. In vegetative (V) growth stages, the tested soybean plants are actively producing more vegetative mass and actively increasing in overall height. The vegetative phase involves exponential increase in biomass (Peterson, 2007). As the soybean plants enter reproductive (R) stages, energy is diverted from the production of vegetative mass to production of reproductive structures and offspring and the increase in biomass now takes on a linear rate (Peterson, 2007). This shift in energy allocations would suggest that measures of height effects on plants are likely to be more pronounced when exposures occur during the vegetative growth states of the plants, and that effects on yield are likely more pronounced when the plants are shifting to reproductive development. Therefore, the concentration that causes a 5% reduction in plant height or yield would be lowest within the most sensitive growth stages for each.

4.4.1 Recent Large Scale Academic Field Studies

Large-scale trials were conducted by the University of Arkansas, University of Wisconsin-Madison, Purdue University, Michigan State University, and University of Nebraska. The protocol for these studies is provided in **Appendix B**. This series of field trials were designed to evaluate off-target movement via spray drift and volatility when applied to large areas (10 – 40 acres). Applications were made under conditions consistent with the current XtendiMax label. Tank mixtures of XtendiMax + PowerMax (active ingredient glyphosate) + Intact (drift-reduction adjuvant) were applied consistent with labeled requirements for nozzles and wind speed restrictions. Off-target movement was assessed via air samplers, horizontal mylar sample collectors, and a bio-indicator crop of non-DT soybean.

Treated areas were planted with Roundup Xtend DT soybeans while the surrounding area was planted with a non-DT soybean of a similar maturity group. Applications are designed to target the largest soybean possible before reaching a flowering stage (~V5-V6). The treated areas were surrounded by non-DT soybean, such that samples could be taken for a minimum of 300 feet (91 m). Sample stations were located at various distances (4, 8, 16, 30.5, 45, 60, 75, 90, 105, 120 m) downwind of the application, determined by the available site-specific wind direction at the time of the study. Residues from sample collectors were sent to the University of Nebraska for analysis. To assess volatility, polyurethane foam (PUF) samples were collected and placed in uniquely labeled containers, to be analyzed by the Mississippi Department of Agriculture State Chemical Laboratory. The PUFs were collected approximately 6, 12, 24, 36, 48, 60, and 72 hours following completion of the application to the entire plot.

Spray drift impacts on non-DT soybean were assessed by comparing plant heights and visual plant response along transects perpendicular to the edges of the field to a distance of 100 m. Plant effects from vapor drift were assessed by covering a portion of the non-DT soybean crop during the application period to prevent exposure to spray drift. The cover was removed post-application. Plant heights were measured approximately 14 and 21 days post-application on ten plants at each distance along each transect. Control (untreated) plants were measured just prior to the application at each site as a measure of inherent variability in the plant sizes across the field. In addition, upwind plant height measurements were taken on the day assessments were made. These measurements were taken at least 50 to 100 m upwind of the "upwind edge" of each sprayed area and in areas where visual dicamba symptomology was not expected.

Visual plant response was assessed on a scale of 0 to 100 with 0 representing no visible plant response and 100 representing complete plant death. This plant response rating scale was conducted consistent with visual plant response ratings described in Frans (Frans, 1977), Behrens and Lueschen (Behrens, 1979), and Sciumbato et al. (Sciumbato et al., 2004). For selected plots and timings, photographs were made to document the visual plant response symptoms, and severity at specified distances.

The sections below discuss the results of these large field studies. While air concentrations and deposition were measured using air samplers and mylar collectors, these values were not provided to EPA. Air sampler analysis was being conducted by the Mississippi Department of Agriculture State Chemical Laboratory, while deposition samplers were being analyzed by University of Nebraska. It is EPA's understanding that these samples are still being processed and will be submitted as soon as they are available. Deviations to the protocol in **Appendix B** were noted in the University of Arkansas study; responses to the deviations are discussed in further detail in **Appendix G**. The remaining study authors were contacted on October 11, 2018 to assess if any of the other large field studies had deviations to the protocol. The study authors (Dr. Werle, Dr. Young, Dr. Sprague, and Dr. Kruger) all responded by October 12, 2018, that there were not deviations from the protocol for their study site.

4.4.1.1 University of Arkansas Results

Dr. Norsworthy from the University of Arkansas (Norsworthy, 2018a) provided results for the field trial conducted in Arkansas, where a 38.5-acre field of DT soybean inside of a larger 240-acre field of non- DT soybean was treated on 7/16/18 at 3 pm. Wind speed during the application varied from 1 mph to 6 mph, with wind direction varying from winds from the west (start) to winds out of the south (completion). As prevailing winds were described as coming from west to east, only one transect was used on the north and south sides of the field. However, based on the wind measurements during the first three days, the majority of the winds were from the south (**Figure 6**). The wind direction profile for the daytime (8 am to 8 pm) hours was consistent with the profile during the nighttime hours (8 pm to 8 am). It should be noted that for 7 days prior to the application, no sustained wind speeds above 3 mph (minimum wind speed limit on the label) were observed. In an effort to apply the Xtendimax before the R2 growth stage occurred (Xtendimax only allows applications up to the R1 growth stage), the application was made on July 16th. Winds after application continued to be low, with the majority of the wind speeds in the range of 0.5 to 2.1 m/s (1 to 5 mph). Buckets were placed on plants every 50 ft, and a 12 x 25 ft^2 tarp was placed on top of soybean plants outside the field to evaluate the impacts of secondary only drift. Air temperatures ranged from 75 to 92°F, soil temperatures were not provided. Relative humidity data during the course of the study were not provided. Plant height measurements along the transects were made at 15 and 22 DAT. There were no significant differences between the height of plants on the upwind and downwind sides of the treated field or with distance away from the field. As noted above, establishing plant height endpoint measurements is reliably established for V stage plants and not for R stage plants. Because the plants in this study were in R stage, height data was not considered reliable for establishing effects distances. At 22 DAT, visual injury was similar for plants exposed to primary spray and secondary volatility drift and those exposed to secondary drift alone. Twenty percent visual injury occurred out to a distance of 200-250 ft (61-76 m). At 29 DAT, 20% visual injury due to drift (it was not specified whether the damage was due to primary or secondary drift) was reported along the east and south sides of the field at approximately 150 ft (46 m) and between 200 and 250 ft (61-76 m) along the west side. Forty percent visual damage along the north side of the field extended beyond 750 ft (229 m), but was attributed to runoff from flood irrigation.

Several deviations from the protocol (as described in **Appendix B**) were noted. UR110-10 nozzles were used instead of the TTI 11004. The UR110-10 are permissible according to the Xtendimax label. The product Warrant (a microencapsulation of acetochlor) was also added to the tank mix. The tank mix was held for 8 days, so the study might have been compromised because there is significant uncertainty as to whether the products were not properly mixed or could have degraded, potentially increasing the volatility of the tank mix, especially given that the Warrant label explicitly states that "Applications made using spray solutions of this product which have been allowed to stand or have been stored in application equipment or the mix tank for an extended period of time *could result in crop injury*." The label for Warrant also indicates that the product should not to be used with irrigation. After learning of this label deviation for this study, EPA considered whether any plant damage reported could be confused with damage allegedly from acetochlor and therefore call into question the study's utility for defining dicamba damage. Subsequent discussions (10/14/2018) with and information provided by Dr. Norsworthy (see **Appendix G**) suggested that the tank mix containing Warrant had no undue effects on the study results and that damage resulting from acetochlor would be easily distinguishable from that caused by dicamba (*i.e.*, acetochlor damage results in a crinkling of the leaf and a wavy appearance, while dicamba damage results in a cupping of the leaf) and none was observed during the conduct of the study (**Appendix G**).

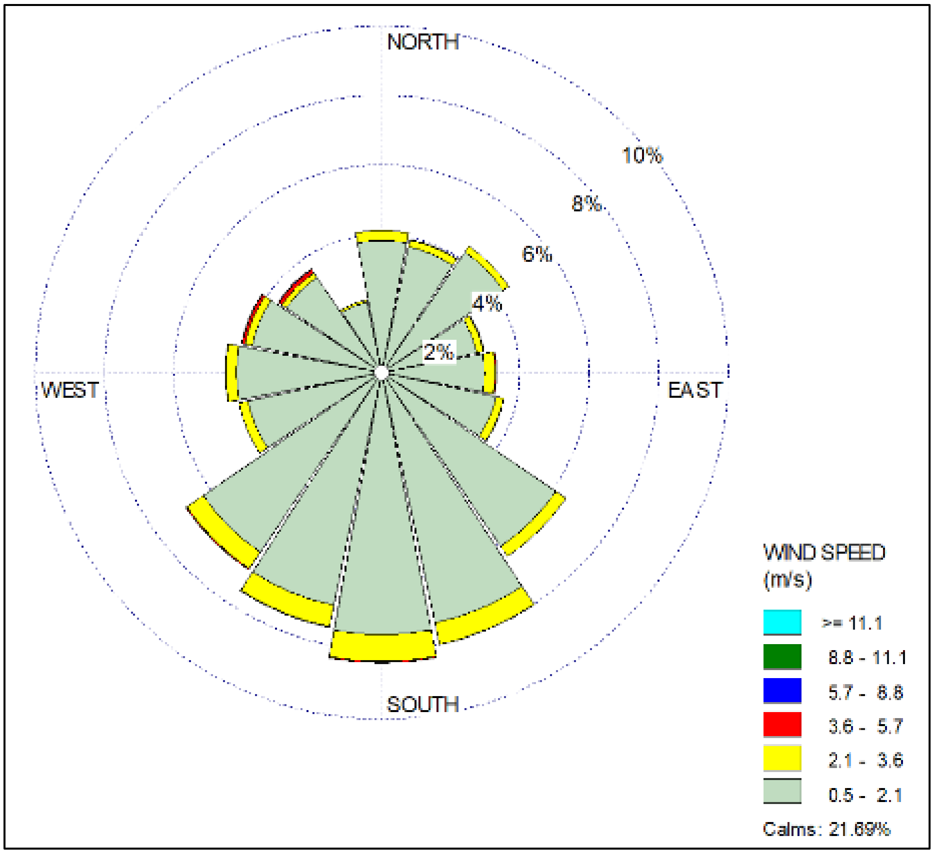

Figure 1. Wind Rose Plot, Norsworthy Study (direction from which wind was blowing)

4.4.1.2 University of Wisconsin-Madison Results

After EPA inquiries regarding additional field studies conducted using dicamba products, Dr. Werle from the University of Wisconsin-Madison also submitted data in support of the large field study effort (Werle, 2018). An 8-acre plot of soybeans at the V5 stage was treated on 7/11/18 from 10:50 to 11:17 am with Xtendimax plus PowerMax. The air temperature during the application was 81°F, while the soil temperature was 75°F. Winds during the application were out of the southeast at 3-6 mph. Temperature during the first 19 days of the study ranged from 49 to 90°F and relative humidity ranged from 42 to 100%. Inversion conditions appeared to occur during the evenings during the course of the study. Soybean was at the V5/V6 growth stage and was 13 inches tall. Three transects along the north side of the field and one transect along the south side were assessed for soybean plant height and visual injury. Plant height measurements along the transects were made at 14 and 28 DAT. This was also the case with for downwind transects with distances away from the field. However, an upwind transect (S-1) had a 5% reduction in height approximately 9 m from the edge of the field Along the north transects, 20% visual injury was reported out to about the 6th-9th row of soybeans at 14 DAT (**Figure 7**) and the 6th-14th row of soybeans at 28 DAT (**Figure 8**). At both times, visual damage for the uncovered plants tended to be higher than those that were covered, indicating that primary and secondary drift played more of a role in the visual damage than secondary drift alone. Each row was approximately 30 inches in width, so the distance would be, at a minimum, 15-23 ft (5-7 m) at 14 DAT and 15-35 ft (5-11 m) at 28 DAT. The south side did not indicate any visual injury to plants. However, it should be noted that winds didn't blow from the north, and blew from the northwest and northeast approximately 22% of the time (**Figure 9**), so it is uncertain if the plants along the single south transect were exposed.

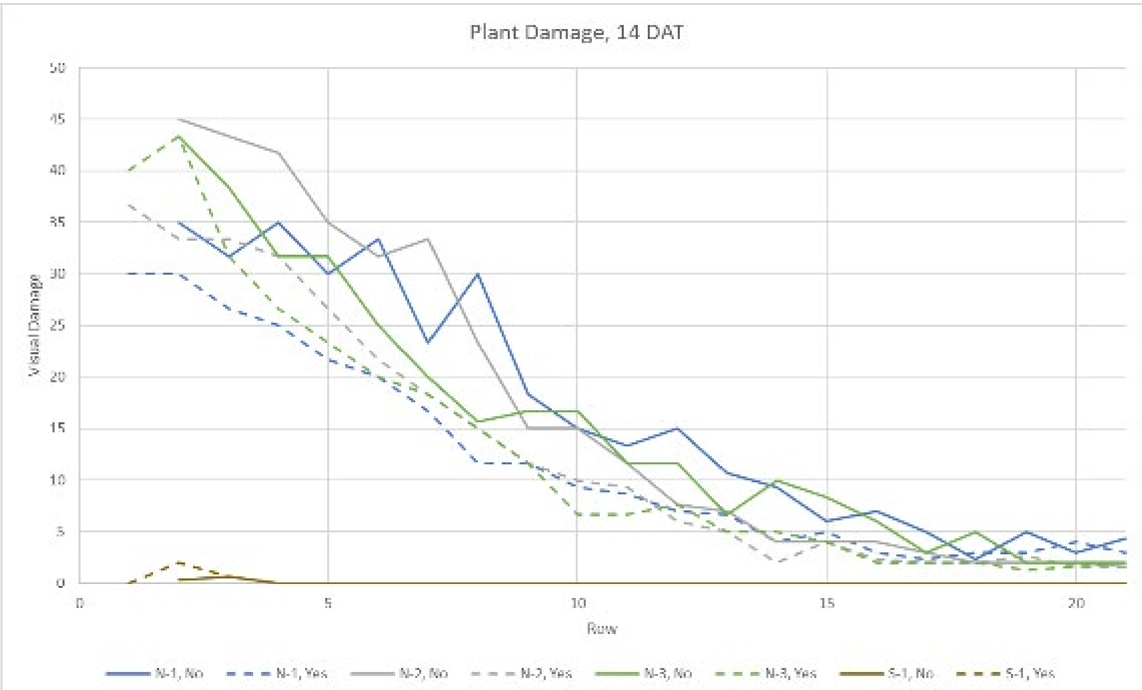

Figure 7. Plant Damage at 14 Days After Treatment, Werle Study

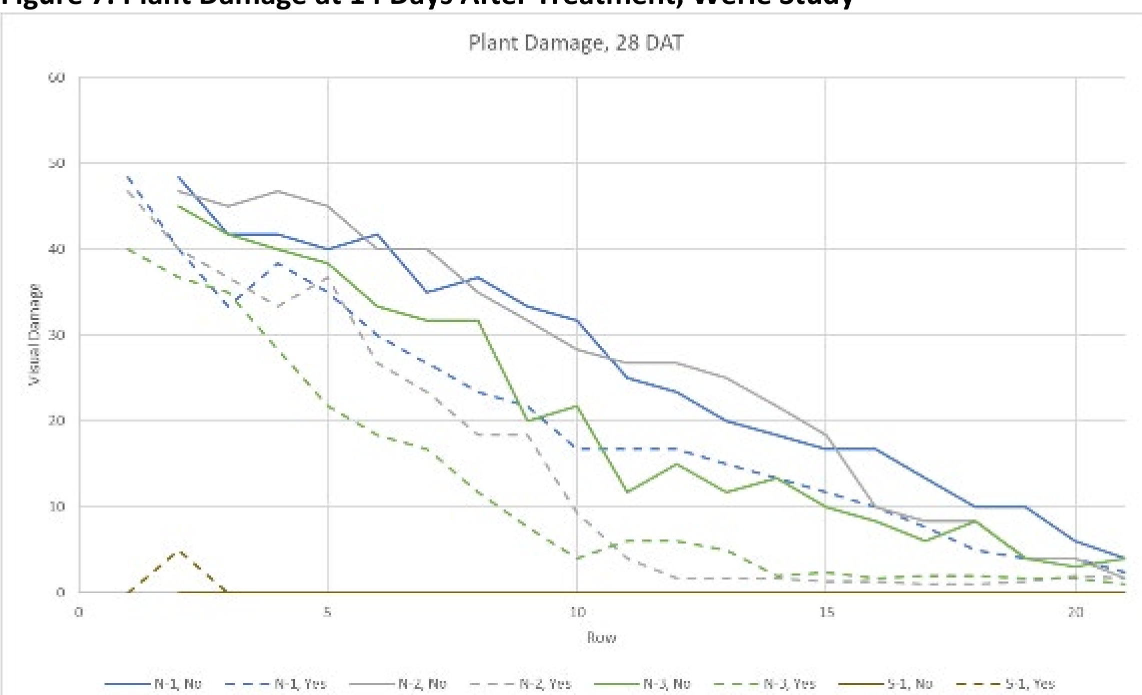

Figure 8. Plant Damage at 28 Days After Treatment, Werle Study

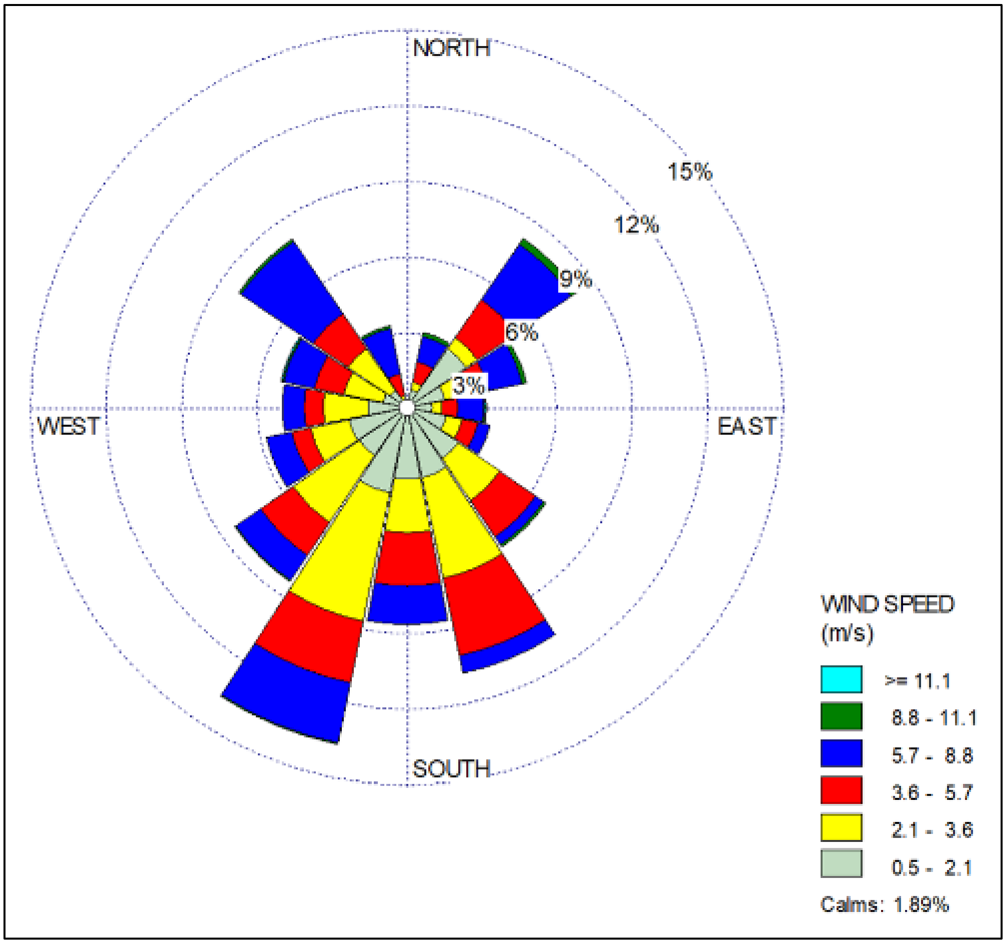

Figure 9. Wind Rose Plot, Werle Study (direction from which wind was blowing)

4.4.1.3 Purdue University Xtendimax plus PowerMax Results

EPA inquired regarding additional field studies conducted using dicamba products and Dr. Young from Purdue University also submitted data in support of the large field study effort (Young, 2018a). A 20-acre plot (1000 ft x 2800 ft) of DT soybeans surrounded by 44 acres of non-DT soybeans at the R1 stage was treated on 8/9/18 with Xtendimax plus PowerMax. The air temperature during the application was 84°F and relative humidity was 64%. Winds during the application were out of the southwest at 1.5-7 mph. Temperature during the first 19 days of the study ranged from 53 to 88°F and relative humidity ranged from 48 to 100%. Soil temperature data were not provided. Inversion conditions appeared to occur during the evenings during the course of the study; in many cases the wind speeds during the inversions were recorded as 0 mph. Three transects along the east side of the field and one transect along the west side were assessed for soybean injury. Three separate transects, 8 ft x 50 ft, along the east side were covered by tarps to evaluate secondary volatility drift only. A series of controls were also assessed for primary (spray drift) and secondary (volatility) drift, but is unclear where these transects were located. Plant height measurements along the transects were made at 14 and 21 DAT. There were no significant differences between the height of plants on the upwind (west) and downwind (east) sides of the treated field or with distance away from the field. However, on the east side of the field, covered plants heights had plant height reductions where the plants that were uncovered did not (**Figure 10**). By 21 DAT, covered and uncovered plant heights were similar. Additionally, control plants showed significant plant height reduction at distances up to 10 ft, at which point the plant heights in the controls were the same as those in the east and west transects. As noted above, establishing plant height endpoint measurements is reliably established for V stage plants and not for R stage plants. Given the issues of control versus treatment initial condition and the field study using R stage plants, EPA concluded that direct measures on plant height for Young were unreliable for establishing distance to effect. Along the east transects, 20% visual injury was reported out to about the 15-20 ft at 14 DAT (**Figure 11**) and the 0-22 ft at 21 DAT (**Figure 12**). At both times, visual damage for the uncovered plants were higher than those that were covered, indicating that primary and secondary drift played more of a role in the visual damage than secondary drift alone. Covered plants did not show visual damage above 10%. Control plants showed significant visual damage inside of 15 ft at both 14 and 21 DAT, but showed similar visual damage to the plants along the east transects beyond 15 ft. The west side did not indicate any visual injury to plants. However, it should be noted that winds only blew out of the west 14% of the time and from the east 6% of the time (**Figure 13**), so it is uncertain how much exposure the plants along the east and west transects received.

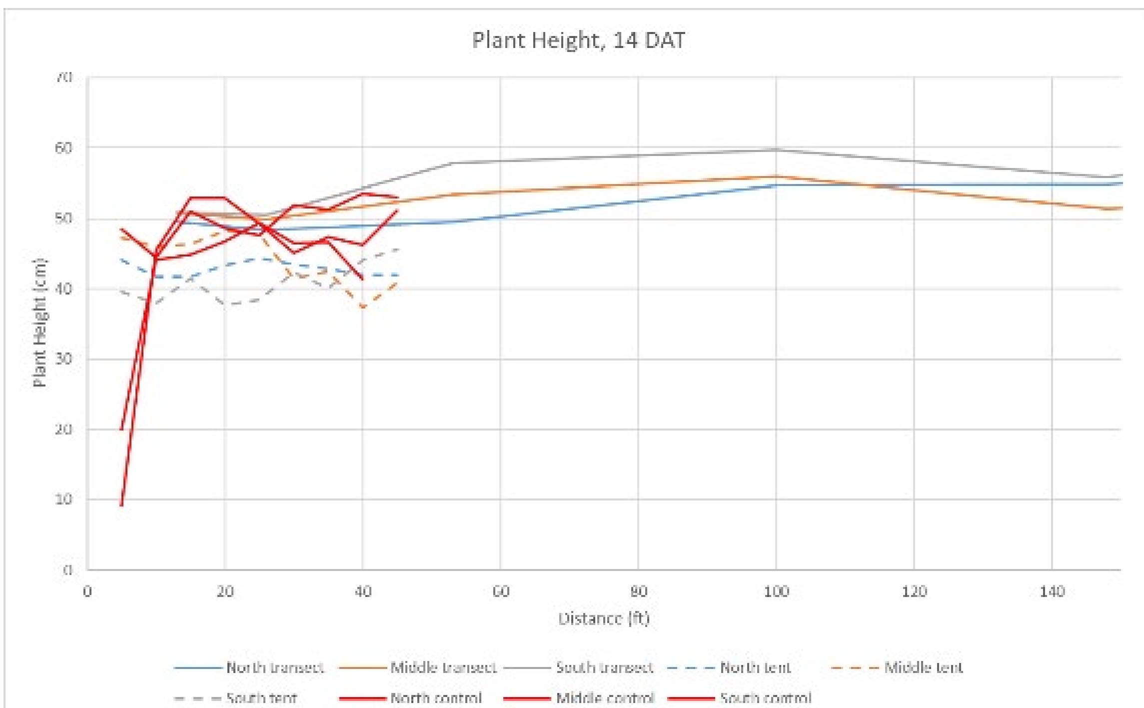

Figure 10. Plant Height 14 Days After Treatment, Young Study

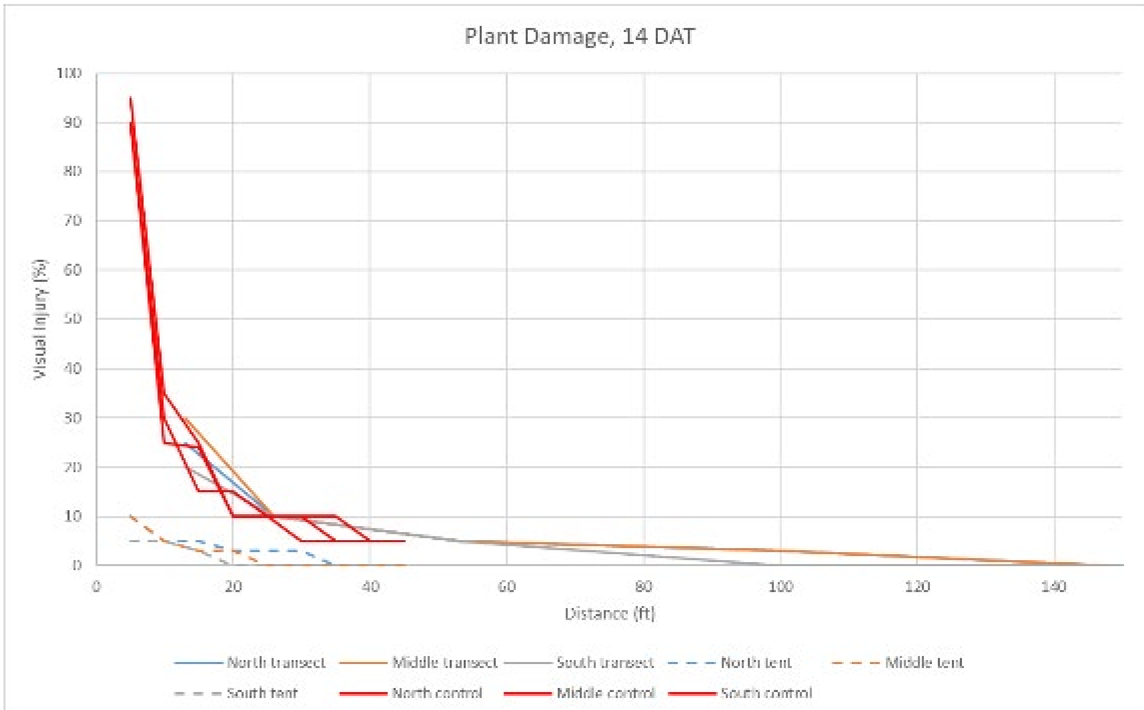

Figure 11. Plant Damage at 14 Days After Treatment, Young Study

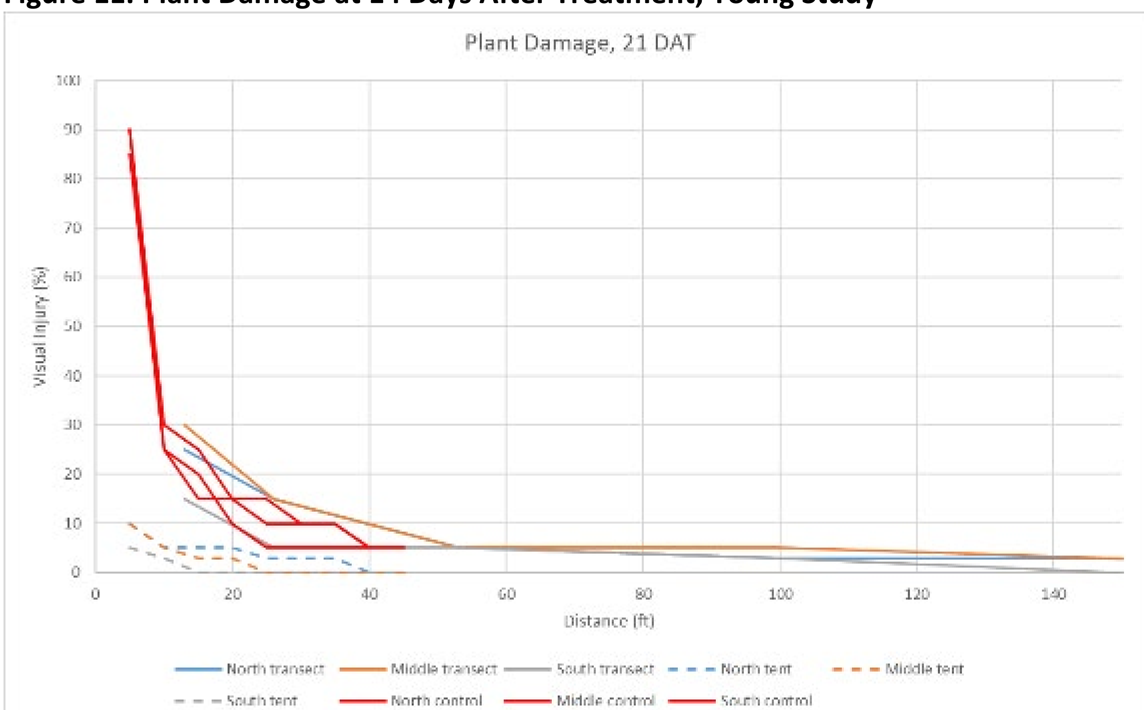

Figure 12. Plant Damage at 21 Days After Treatment, Young Study

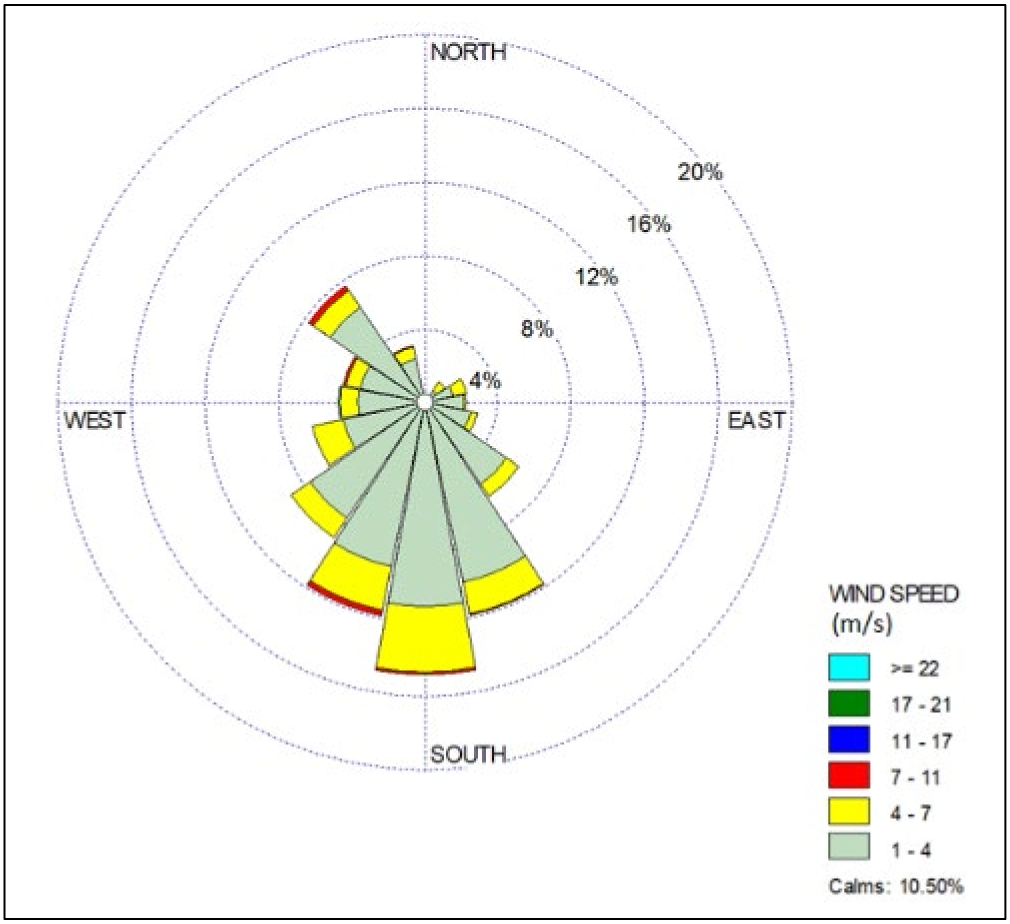

Figure 13. Wind Rose Plot, Young Study (direction from which wind was blowing)

4.4.1.4 Michigan State Results

EPA inquired regarding additional field studies conducted using dicamba products and Dr. Sprague from the Michigan State University submitted data in support of the large field study effort (Sprague, 2018). A 53-acre plot of a 300-acre field was planted with DT soybeans surrounded by non-DT soybeans on May 4-6, 2018. Xtend soybeans were treated at the V3 stage on 6/12/18 with Xtendimax plus PowerMax between 10 and 11 am. The air temperature during the application was 71°F and relative humidity was 78%. Soil temperature data were not provided. Winds during the application were out of the east to southeast at 3-7 mph. Temperature during the first 9 days of the study ranged from 53 to 93°F and relative humidity ranged from 25 to 99%. It should be noted that air temperatures only exceeded 90F (when greater volatility and potential for secondary movement were to occur) for two short periods (4 hours) 5 and 6 days after application. It is uncertain if inversion conditions occurred during the study as temperature at different heights was not available. Winds were primarily out of the northeast and southwest during the study (**Figure 14**). Two transects 120 m in length along the north side of the field (Transects B and C) and one transect along the west side (Transect A), near the northwest corner of the field, were assessed for soybean injury. Tarped regions, 12 ft x

50 ft, near the three transects in the north and west, were covered to evaluate secondary drift only. A series of untarped and tarped upwind areas, 8 to 30 m from the field, were also assessed for primary and secondary drift. Plant height measurements along the transects were made at 14 and 21 DAT. Plants along Transect A appeared to show signs of reduced height (based on a comparison with other transects) up to approximately 25 ft (8 m) from the edge of the field at 14 and 21 DAT; transects to the north did not appear to show signs of plant height reductions except at a distance of between 246 to 344 ft (75 to 105 m) away where study authors noted a low area that appeared affected (**Figures 15** and **16**). Although EPA was unable to estimate plant height reductions using regressions(due to poor regression fit of the data), visual interpretation puts 21-DAT height inhibition for Transect A, relative to other transects at approximately 10 meters for Transect A. Note, the analysis of the data for this study does not necessarily establish a 5% plant height reduction endpoint for Transect A, but rather, a point of departure for plant height along Transect A, relative to transects showing no demonstrable height effect. EPA is using this point of departure as a surrogate for the 5% plant height threshold, which in turn is used as an endpoint when a NOAEC is not available.

Two of the transects, one in the north and the west transect, showed signs of visual injury, with distances to 20% visual injury reported out to about 13-26 ft (4-8 m) at 14 DAT (**Figure 17**) and 26-52 ft (8-16 m) at 21 DAT (**Figure 18**). At both times, tarped plants exhibited no signs of visual damage at 14 DAT and < 20% damage at 21 DAT for the entire 50 ft (16 m) distance, indicating that primary drift played more of a role in the visual damage than secondary drift alone. Upwind plants showed 20% visual injury at distances less than 2.5 ft (0.8 m) from field at 21 DAT. Substantial variability was observed across the other two transects. 21-DAT 10% visual injury, relative to controls, was observed out to approximately 25 meters in two transects, but only 5 meters in the third.

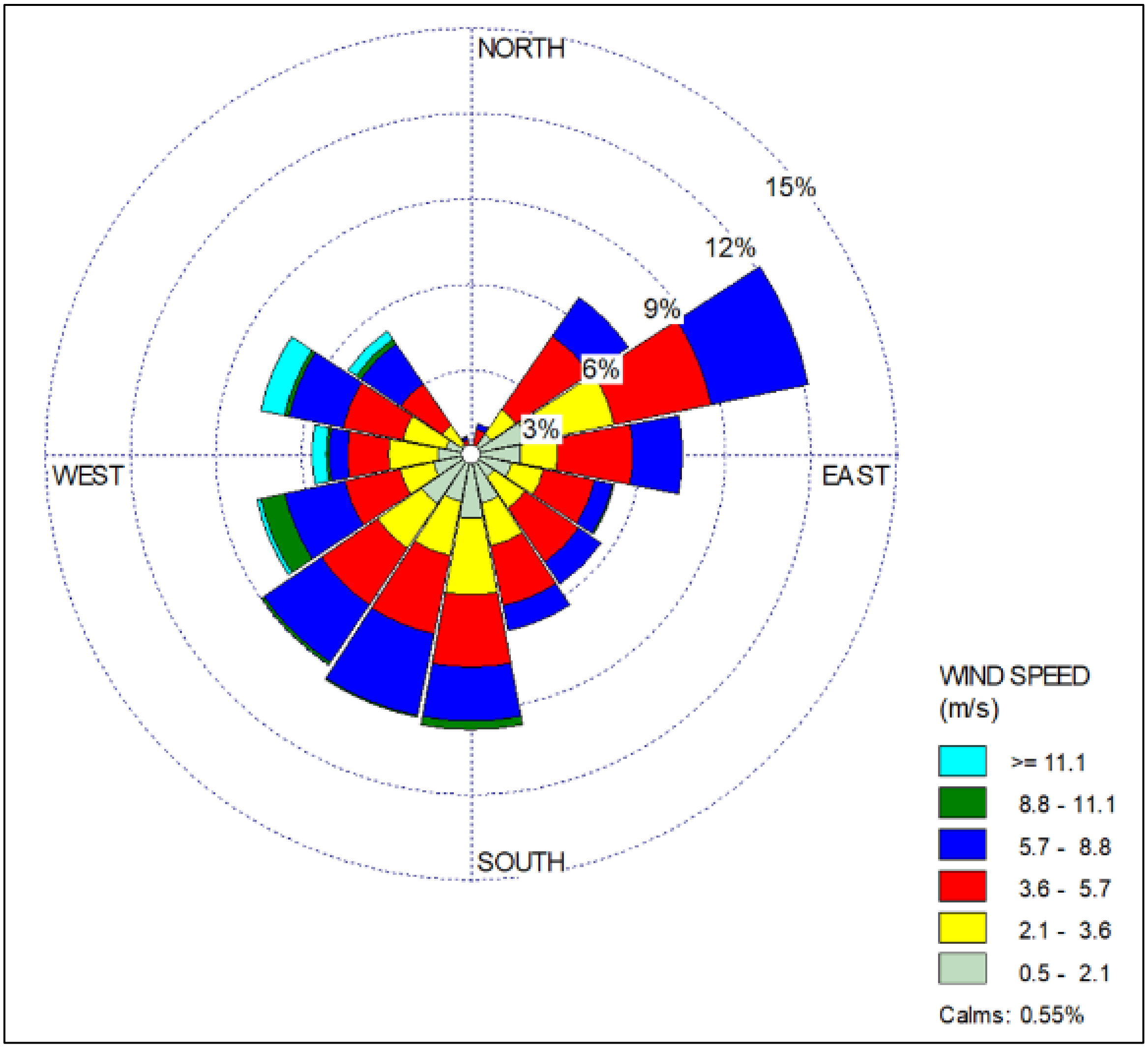

Figure 14. Wind Rose Plot, Sprague Study

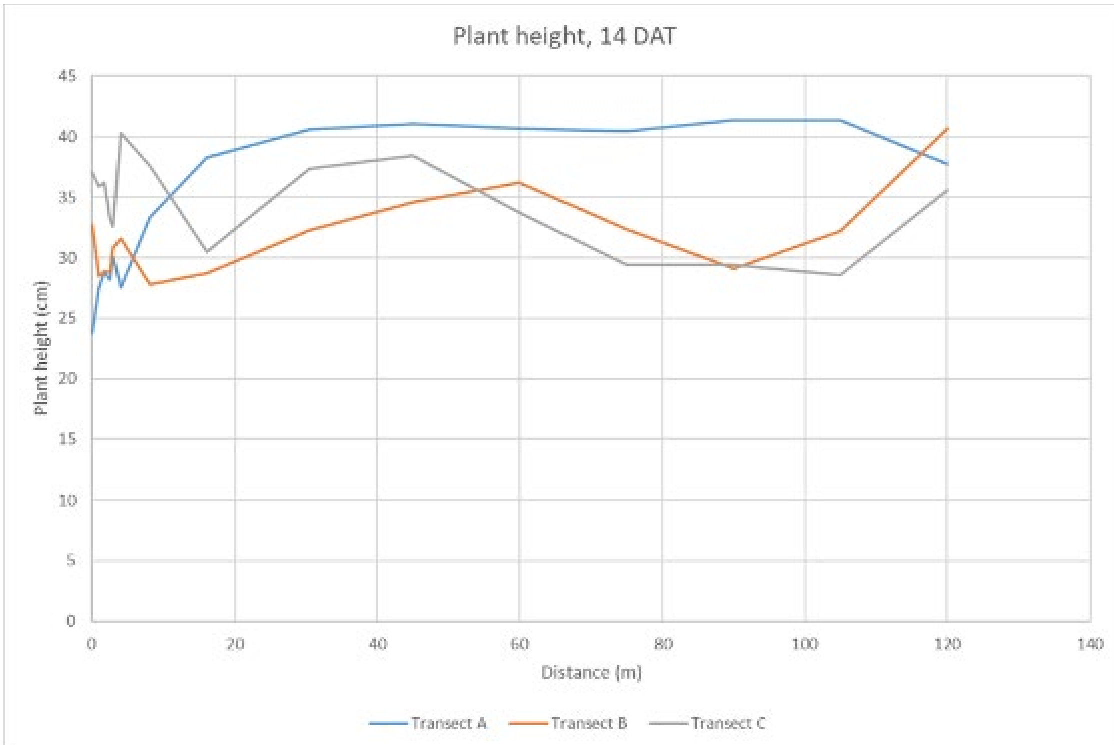

Figure 15. Plant height, 14 DAT, Sprague Study

Figure 16. Plant height, 21 DAT, Sprague Study

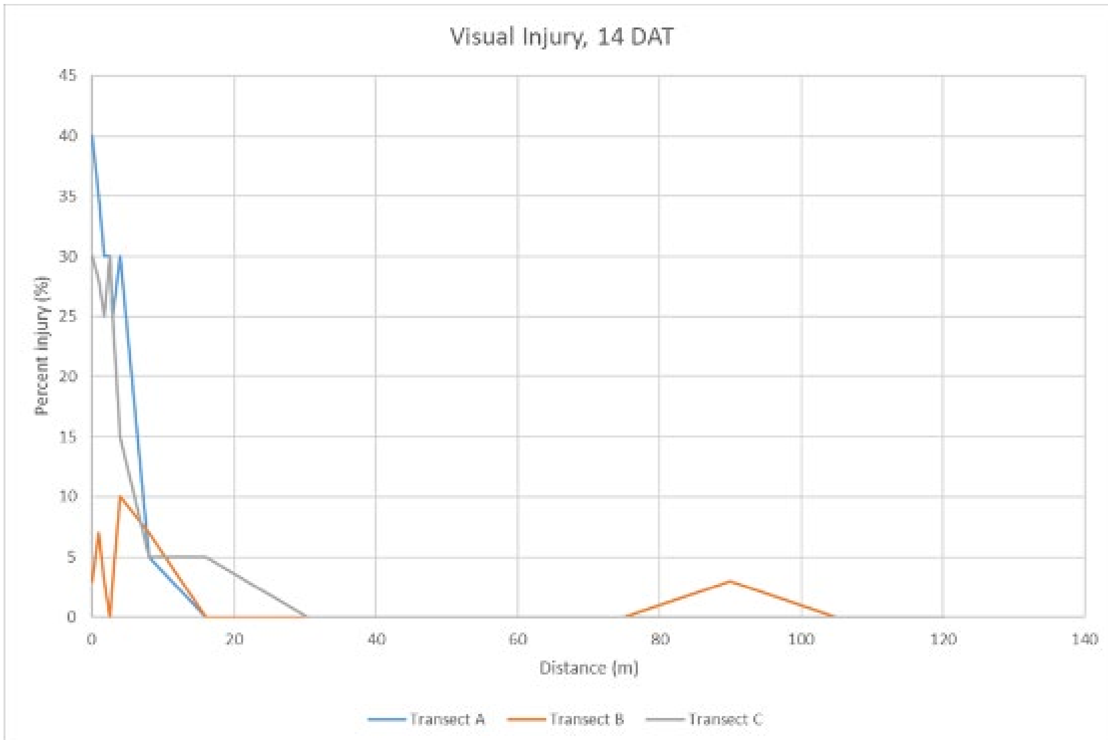

Figure 17. Visual damage, 14 DAT, Sprague Study

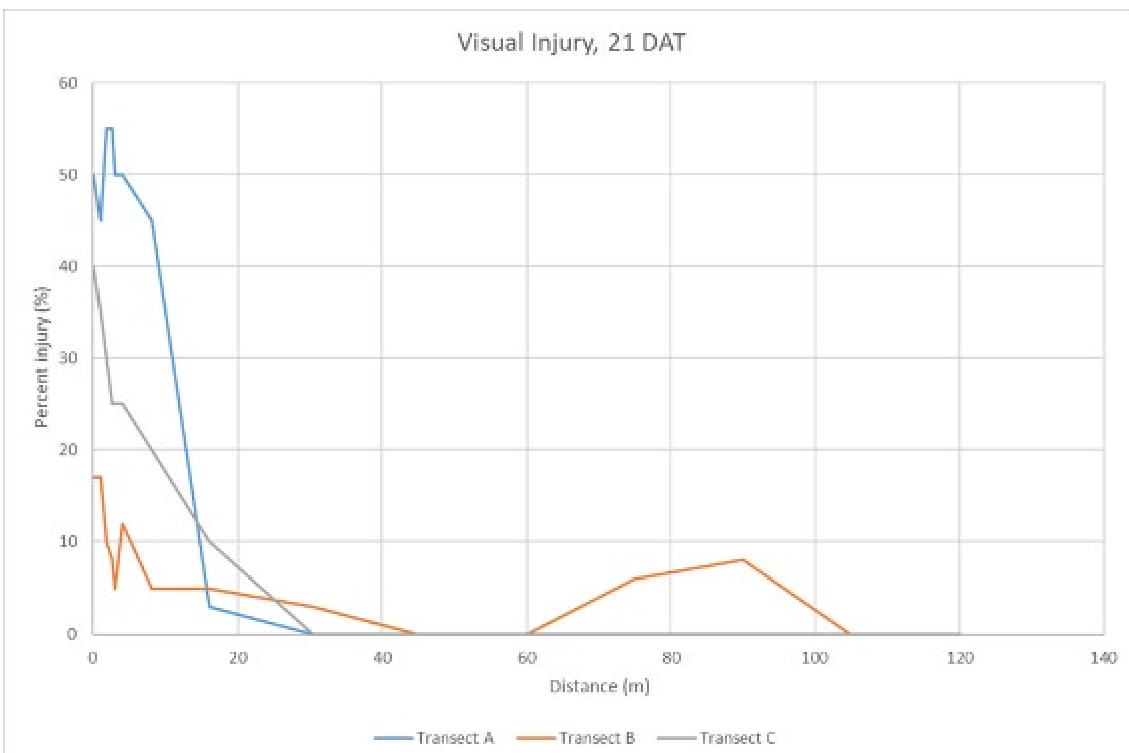

Figure 18. Visual Damage, 21 DAT, Sprague Study

4.4.1.5 University of Nebraska Results

EPA inquired regarding additional field studies conducted using dicamba products and Dr. Kruger from the University of Nebraska also submitted data in support of the large field study effort (Kruger, 2018). A 30-acre plot of soybeans inside of a 150-acre field was treated on 7/10/18 from 8:46-9:09 am with Xtendimax plus PowerMax. Soybean was at the V5 growth stage and was 14 inches tall. The three downwind transects were placed to the north of the field and the upwind samplers were placed on the south. The wind direction was out of the south-southeast at the time of application. No precipitation occurred during the study. Air temperature and relative humidity data for the study were not available. Plant height effects at 21 days beyond 50 feet (15 m) were not observed, regardless of the direction from the application area. The average distance to 5% plant height reduction for the three transects was 10 m. Covered plants did not show a change in plant height with distance. Plots of visual injury with distance for the uncovered transects are provided in **Figure 19**. Slight visual symptomology was observed approximately 250 feet (76 m) beyond the edge of the field. Visual injury to covered plants at 21 days did not vary with distance for two of the transects, but did for the third. Visual injury ranged from 25-40% at 30 feet (9 m) from the treated field for covered plants.

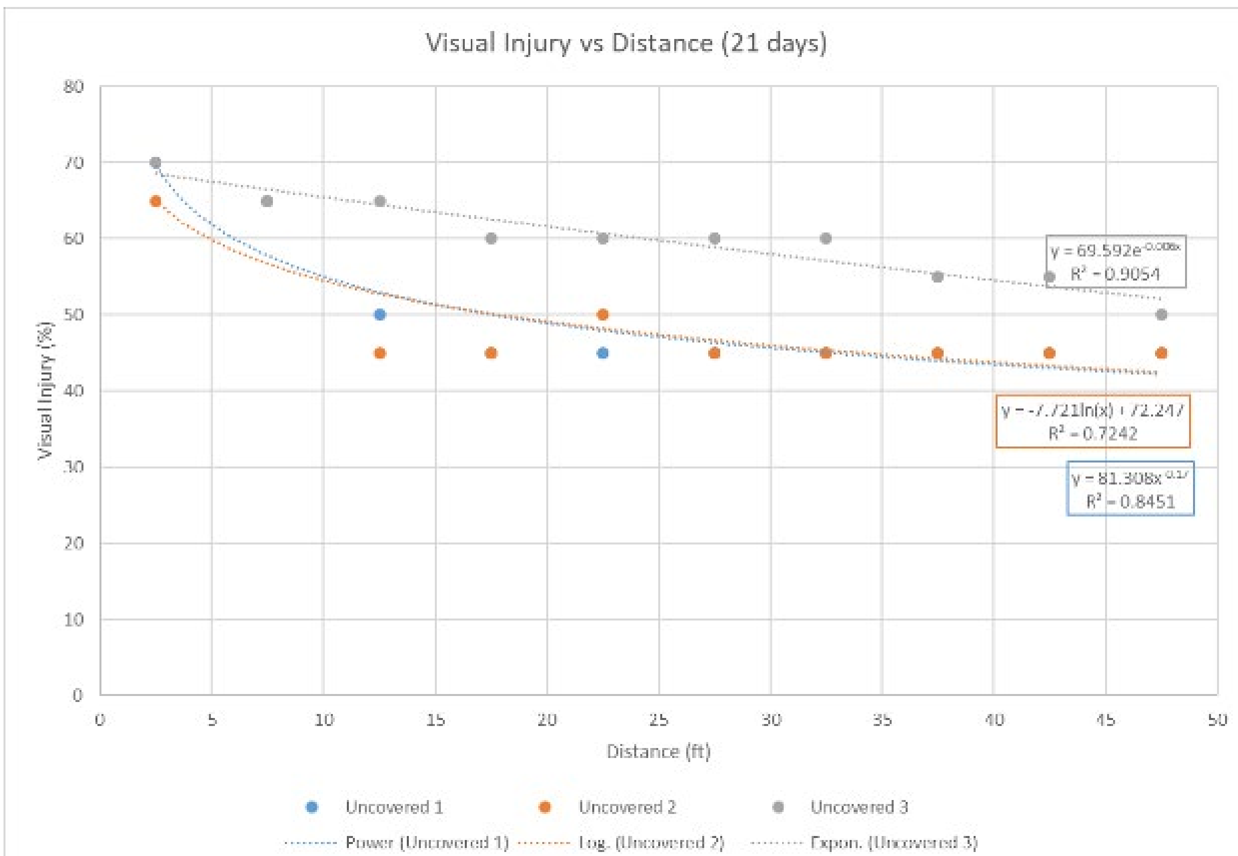

Figure 19. Visual Injury, 21 DAT, Kruger Study

4.4.1.6 Purdue University, Engenia Results

EPA inquired regarding additional field studies conducted using dicamba products and Dr. Young from Purdue University also submitted data for DT soybeans treated with Engenia (Young, 2018b). Two separate plots, each 0.9 acres (200 ft x 200 ft) of DT soybeans in the center of a 15-acre field (800 ft x 800 ft) of non-DT soybeans at the V5 stage, were treated on 8/3/2018 at 3:30 pm. Plots were treated 24 and 48 inches above the canopy, using TTI11003 nozzles (it should be noted that the Engenia label specifies that the boom height should not exceed a height of 24 inches above the crop canopy). During the application, the air temperature was 87ºF, the soil temperature was 95°F and the relative humidity was 56%. Winds during the application were out of the southwest at 1-5 mph. Temperature during the first 28 days of the study ranged from 51 to 91°F and relative humidity ranged from 34 to 100%. Wind speed and wind direction are depicted in **Figure 20**. The majority of the time the wind was blowing from the southwest. Meteorological data were not available to assess whether inversion conditions occurred during the study. Visual plant injury measurements were taken at 14 and 28 DAT every 40 ft on all sides of the field, with additional measurements along a 45 degree at each corner. Three measurements were taken along each transect; the distance to where the extent of symptoms > 30%; the distance to where the extent of >10% symptoms; and the distance to where no symptoms would be visible. Plant heights were not measured in this study. Visual injury results are provided in **Table 2**. At 14 DAT, the maximum average distance to greater than 30% visual injury occurred along the north side at 31 ft, with a maximum distance to greater than 30% injury at 82 ft (east side) for plot 1. At 28 DAT, the maximum average distance to greater than 30% visual injury occurred along the east side at 26 ft, with a maximum distance to greater than 30% injury at 108 ft for plot 1. Plot 2 results are also provided in **Table 2**, but these results were generated using a boom height 48 inches above the canopy, which is in violation of the label.

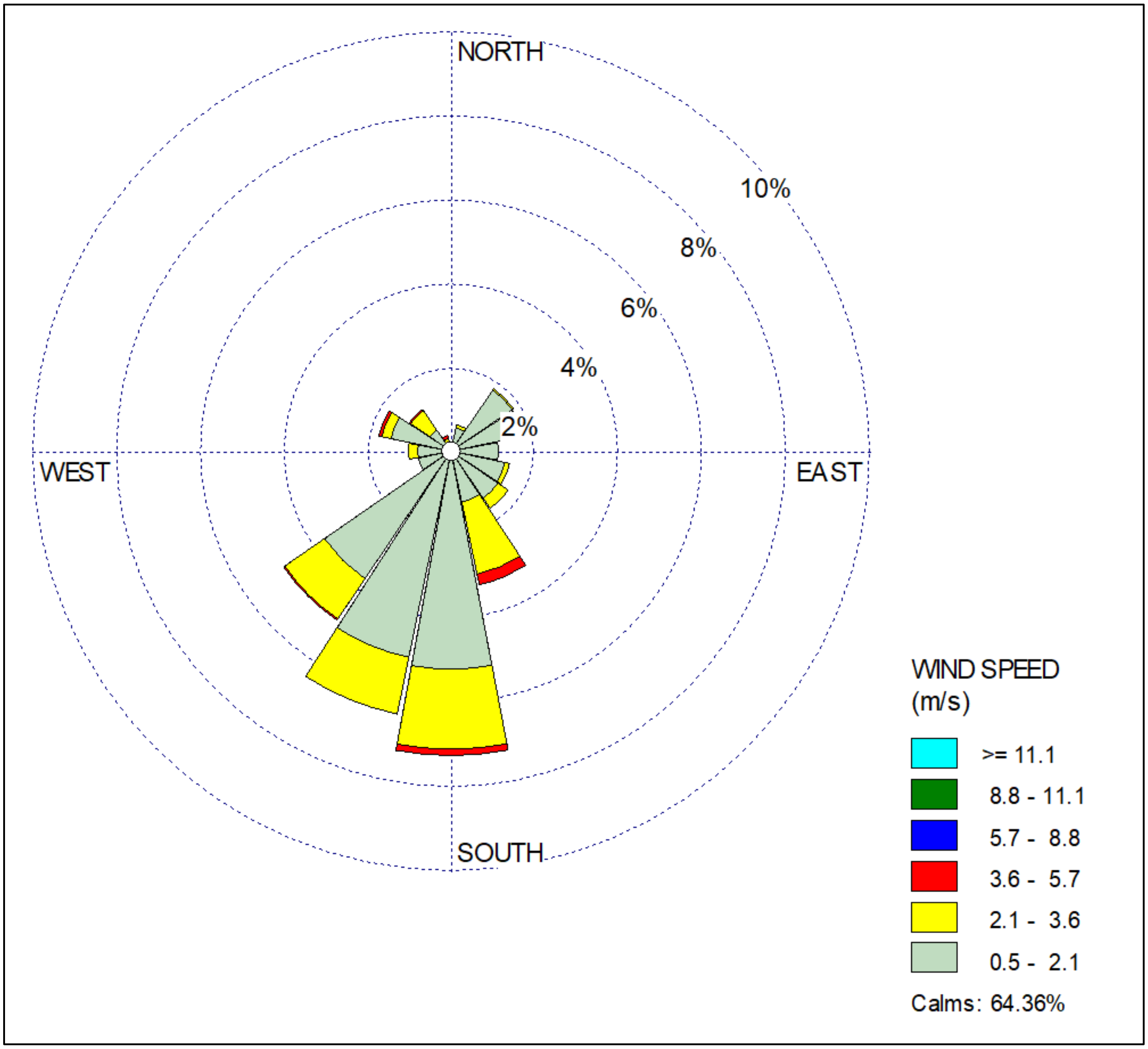

Figure 20. Meteorological Data, Young Engenia Study

Table 2. Distance to Visual Injury (m) from Young (2018) under Engenia Application

Side/Transect	14 DAT Average Distant (Min – Max)			28 DAT Average Distant (Min – Max)		
	> 30%	10-30%	< 10%	> 30%	10-30%	< 10%
Plot 1						
North	10 (3 – 21)	16 (5 – 43)	19 (6 – 50)	5 (2 – 18)	11 (4 – 19)	13 (5 – 23)
East	7 (1 – 25)	11 (1 – 33)	21 (5 – 34)	8 (0 – 33)	10 (1 – 33)	12 (1 – 34)
South	0 (0 – 1)	1 (0 – 2)	5 (2 – 8)	0 (0 – 1)	0 (0 – 1)	1 (0 – 3)
West	1 (1 – 3)	3 (2 – 5)	6 (3 – 7)	1 (0 – 3)	2 (1 – 4)	3 (1 – 5)
Diagonals	2 (0 – 5)	4 (1 – 8)	8 (2 – 11)	1 (0 – 3)	4 (0 – 8)	4 (1 – 9)
Plot 2						
North	31 (1 – 80)	31 (11 – 55)	34 (16 – 59)	27 (1 – 79)	32 (3 – 80)	41 (10 – 81)
East	11 (2 – 16)	15 (2 – 21)	21 (5 – 29)	8 (1 – 12)	22 (8 – 29)	32 (8 – 44)

South	51 (0 – 135)	34 (2 – 102)	65 (4 – 129)	17 (0 – 96)	20 (1 – 98)	34 (4 – 100)
West	1 (1 – 2)	2 (2 – 4)	4 (2 – 5)	1 (0 – 2)	2 (1 – 3)	3 (2 – 4)
Diagonals	(7 (0 – 26)	10 (1 – 36)	24 (3 – 52)	3 (0 – 10)	11 (1 – 39)	18 (2 -62)

4.4.1.7 2017 Field Studies

In 2017, a series of small-scale field studies (0.17 – 3.5 acres) were conducted in Nebraska, Indiana, Arkansas, Tennessee, and Missouri (Norsworthy, 2018b). Studies looked at plant effects (visual injury and plant height) to spray drift and volatility to soybean plants in the downwind direction from a field treated with Xtendimax or Engenia. A summary of the field conditions is provided in **Table 3**.

Table 3. Study Conditions, 2017 Small Scale Trials

Application Info	**NE**	**IN**	**AR**	**TN**	**MO**
Study Conductor	Kruger	Young	Norsworthy	Steckel	Bradley
Application date	7/6/2017	8/27/2017	7/20/2017	7/27/2017	7/20/2017
Start time	11:00 AM	3:04 PM	11:56 AM	10:45 AM	11:00 AM
Stop time	11:19 AM	3:19 PM	12:19 PM	10:52 AM	11:20 AM
Avg. air temp during application (F)	88	79	94.2	84.2	88.9
Max. air temp day of application (F)	100.7	82.3	96.4	91.5	94.9
Relative humidity during application (%)	46.3	47	59.4	84	60
Avg. wind speed during application (mph)	5.25	4.2	2.9	3.3	5.3
Wind direction during application (degrees)	250	80	259	225	240

Plant height data were only available for the Arkansas field trial. Height measurements for control plants were not provided, so the average height of the plants at the last three distances (85, 91, and 97 m) were used as a surrogate for controls to evaluate plant height effects with distance. For the Arkansas field trial, at 25 DAT, height effects were not significantly different across the transects or among them for the trial conducted using Xtendimax. For the trial conducted using Engenia, height effects were significantly different when comparing the plant heights at 3 to 9 m distances to the plant heights at distances greater than 60 m.

Based on an analysis of the visual injury reported versus distance for each trial, the distance to 20% visual injury is provided in **Table 4**. It should be noted that the trial conducted in Nebraska may have been compromised, as an application occurred to a nearby field that may have impacted the results.

Table 4. Summary of Distances (meters) to 20% Injury for Primary and Secondary Exposures

Product	**Exposures**	**Distance (m)**				
		NE	**IN**	**AR**	**TN**	**MO**
Xtendimax	Primary and Secondary Exposure	43	<10	31	5	19
Xtendimax	Secondary Exposure only	35	<10	18	0	3

Engenia	Primary and Secondary Exposure	36	<10	24	13	8
Engenia	Secondary Exposure only	29	<10	11	1	2

It should be noted that meteorological data for the duration of the study trials were not provided, so it is uncertain if the wind blew the majority of the time in the direction of the soybean plants that were analyzed. Completion of a review for these studies will require additional information, in the form of a study report, and a better understanding of the nature of the field trials.

4.4.3.8 Additional large field study data

In 2018, Gordon Travis Jones, a Master of Science in Crop, Soil, and Environmental Sciences student at the University of Arkansas, evaluated the effects of dicamba on soybean plants for his master's thesis. Jones (2018, chapter 4) conducted field experiments in 2015 and 2016. Glufosinate-resistant soybean (Bayer Credenz 4950LL) was planted in two adjacent 8-ha (19.8 A) fields on June 15, 2015, and June 13, 2016. Rows were bedded on 97-cm centers. A 38- by 38-m area (0.144 ha, 0.36 A) in the center of each field simultaneously received either DGA or BAPMA dicamba applied at 560 g ae/ha (0.5 lb ae/A) with Bowman Mudmaster high-clearance sprayers. Applications were made at the soybean V6/V7 growth stage in 2015 and the V4/V5 growth stage in 2016. Each sprayer was equipped with a broadcast boom having a 7.6-m swath tipped with TTI11003 nozzles (TeeJet Technologies) calibrated to deliver 94 L/ha (10 gal/A) at 275 kPa (40 psi) while traveling at 15 km/h (10 mph). Five passes were made simultaneously for each chemical to reduce variation in wind, humidity, and temperature. Wind speeds were recorded at 1-s intervals during the application. Relative humidity and temperature were recorded at the beginning and end of the application. Daily weather data (wind speed, wind direction, temperature, humidity) on a 15-s interval were recorded from 1 week before application to 3 weeks after application using a weather station placed between the two fields. Prior to application, transects were laid out in each of the eight cardinal directions extending to the edge of the field. Plots were established every 3 m from 3 to 12 m from the sprayed area, every 6 m from 12 to 36 m, every 9 m from 36 to 72 m, and every 12 m beyond 72 m until the edge of the field was reached. Two subplots consisting of four to five soybean plants per subplot were marked at each distance. The subplots consisted of soybean plants that were exposed to a) primary plus secondary drift or b) secondary drift only (any exposure more than 30 min after application). Immediately before application, 19-L buckets were placed over the soybean plants in subplots that were exposed only to secondary drift. Buckets were removed from these plants 30 minutes after completing the spray application (secondary drift only). The primary plus secondary drift subplot was never covered.

Additionally, metal rebar stands were erected with a 20 by 20 cm plywood platform affixed to the rebar at the height of the soybean canopy just before spraying. These stands were placed within the treated area and at each plot in 2015. In 2016, stands were again placed in the treated area but only in plots up to 30 m from the application. Four petri dishes (63 cm^2 in size) were placed on separate stands within the treated area to catch a full rate of dicamba. Mylar cards were placed on the stands outside of the treated area to catch primary drift. In 2015, 100 cm^2 mylar cards were placed on stands at 3, 6, 9, and 12 m from the application. Mylar cards 400 cm^2 in size were used at plots starting at 18 m to the field border. In 2016, 400 cm^2 mylar cards were used from 3 to 30 m. In order to quantify primary drift, rhodamine dye (Sigma-Aldrich Company) was placed in each spray tank at 1 g/L. Petri dishes and mylar cards were removed from the field 30 min after application and placed in plastic bags indicating their location and then in a dark cooler to prevent photodegradation of the dye. Petri dishes and mylar cards were taken to the University of Nebraska Pesticide Application Laboratory in North Platte, NE, to quantify the amount of dye present on each surface using fluorimetry.

Injury to soybean within each subplot (primary plus secondary, secondary) was rated at 7, 14, and 21 days after application (DAA). Injury was rated on a 0 to 100% scale with 100% being plant death. There was no attempt to solely quantify primary drift because this would have required plants be covered for several days with buckets. Injury to soybean outside of the treated area was primarily in the form of leaf cupping, but also included leaf crinkling, epinasty, and terminal death. Two soybean plants exposed to primary plus secondary drift were harvested at 7 DAA in 2015 and four plants in 2016 directly adjacent to all distances that were rated for injury. Samples were transported on dry ice to the Arkansas State Plant Board in Little Rock, AR, and analyzed for dicamba remaining in the tissue. The method of dicamba extraction and quantification was GC/MS. The limit of detection was 1 ppb.

Jones reported that the ambient air temperature was 38°C (100°F) in 2015 and 30°C (86°F) in 2016 at the time of application whereas relative humidity was 44% in 2015 and 77% in 2016. These and other environmental conditions are considered typical for over-the-top applications, but not necessarily worst-case conditions, especially for 2016 when the temperature was cooler than 2015. Wind speed ranged from 4 to 12 km/h (2.5 to 7.5 mph) in 2015 and 10 to 16 km/h (6.2 to 10 mph) in 2016. Winds were primarily in a north/northeastern direction during and for 48 h after application both years; therefore, soybean injury was mainly confined to the north, northeast, and east transects.

Injury resulting from primary plus secondary drift generally occurred along transects at further distances following application of the DGA (Clarity) than the BAPMA (Engenia) salt of dicamba in 2015. In the 2015 experiment, the maximum distance to 5% injury from primary and secondary drift was 30 m for DGA and 24 m for BAPMA. The maximum distance to 5% injury from secondary drift alone was 12 m for DGA and BAPMA. In 2016, the maximum distance to 5% soybean injury from primary and secondary drift was 168 m for the DGA salt and 96 m for the BAPMA salt. The maximum distance to 5% soybean injury from secondary drift alone of the DGA salt (120 m) was over twice as far as the BAPMA salt (54 m). However, it is unclear what impact primary and secondary drift had on crop yield or pod malformation, as these effects were not evaluated. The droplet spectrum difference in VMD was 13 microns between DGA (757 µm) and BAPMA dicamba (744 µm). In addition, the percentage of fines (droplets < 210 µm) was equivalent for the two formulations (1.57% of total spray volume).

Measurements of primary drift using mylar cards resulted in only two positive readings in 2015 and nine positive readings in 2016. Either the use of mylar cards in combination with fluorimetry does not appear accurate enough to quantify the extremely low rates of primary dicamba drift capable of causing injury to soybean, or observed effects in this study were primarily a result of secondary drift.

Results from the rate response (see discussion in Section YY) experiment indicate that soybean is equally sensitive to DGA and BAPMA dicamba. It should also be noted that six to eight hours after application of the large drift trial in 2015, a rain event occurred, potentially limiting volatility by incorporating some of the herbicide into the soil.

4.4.4 Analysis Summary of Academic Field Studies

Table 5 provides a summary of the effects observed in the 2018 large, 2017 small field trials, and Jones 2018, relative to whether the damage occurred via secondary drift alone, or due to a combination of primary and secondary drift. From an analysis of the data summarized in the table, it appears that while secondary drift alone does cause visual damage to plants surrounding a treated field, in most cases primary plus secondary drift results in greater damage. Data are only available for two of the studies such that plant height reduction could be assessed for secondary drift only. In those cases, secondary drift alone did not appear to cause plant height reductions.

Table 5. Summary of Results from Large and Small Field Trials

Study	Product Used	Visual Injury		Plant Height Reduction	
		Secondary Drift Only Effects?	Primary + Secondary Drift Effects?	Secondary Drift Only Effects?	Primary + Secondary Drift Effects?
2018 Large Field Studies					
Norsworthy (AR)	Xtendimax	Yes	Yes	Not reliable	Not reliable
Werle (WI)	Xtendimax	Yes, lower than combined primary + secondary	Yes	No	Upwind transect only
Young (IN)	Xtendimax	Yes (<10%), lower than combined primary + secondary	Yes	Not reliable	Not reliable
Sprague (MI)	Xtendimax	Yes (<20%), lower than combined primary + secondary	Yes	No	Downwind transect along west side
Kruger (NE)	Xtendimax	Yes, lower than combined primary + secondary	Yes	No	Yes

Study	Product Used	Visual Injury		Plant Height Reduction	
		Secondary Drift Only Effects?	Primary + Secondary Drift Effects?	Secondary Drift Only Effects?	Primary + Secondary Drift Effects?
Young (IN)	Engenia	Damage observed around entire field, not just wind direction during application	Yes	Not assessed	Not assessed
2017 Small Field Studies					
Kruger (NE)	Xtendimax & Engenia	Not assessed	Yes	Not provided	Not provided
Young (IN)	Xtendimax & Engenia	Not assessed	Yes	Not provided	Not provided
Norsworthy (AR)	Xtendimax & Engenia	Yes, wind blew to northeast during application, and east later[1]	Yes, winds blew to northeast during application, and east later[1]	Not provided	Yes
Steckel (TN)	Xtendimax & Engenia	Not assessed	Yes	Not provided	Not provided
Bradley (MO)	Xtendimax & Engenia	Not assessed	Yes	Not provided	Not provided
Open Literature					
Jones (AR	Engenia	Yes, lower than combined primary + secondary	Yes	Not assessed	Not assessed

1. Based on presentation depicting extent of damage around treated fields, not on submitted visual injury data.

Table 6 provides a listing of the strengths and weaknesses of the approach taken in the large and small field studies. While the studies provide a real-world evaluation of the combined effects of primary and secondary drift to non-target plants, the varying meteorological and field conditions lend uncertainty to comparing results across the different studies.

Table 6. Strengths and Weaknesses for Field Studies

Strengths	Weaknesses
Evaluation of effects from spray drift and volatility	Varied meteorological conditions, confound comparisons between sites.
Field studies showing real-world effects	Most studies used transects of plants in downwind/upwind direction. No evaluation of plant impacts when wind changes.
Studies reflect areas reporting significant number (43%) of incidents in 2018	Use of tarps may have resulted in plant damage
Studies done under same protocol to allow for comparison across regions	Some studies were done at R growth stage, making plant height measurements

	unreliable. These were not included in any distance analyses. For R stage, plant yield would be the preferred measurement, but was not available for any study.
Large field studies more reflective of what occurs in environment	No measurement of yield for R growth stage studies
	Most studies done when temperatures were in the low 90s
	Visual damage is subjective measurement, which is why plant height was preferred for V stage trials when both were available in the study.

Based on the majority of the studies, the 110 ft (33.5 m) in-field, unidirectional buffer appears to be sufficient to protect off-site plants from reductions in plant height due to primary drift. However, it is evident from a subset of the field studies that secondary drift also occurs. Because these data suggest an off-site secondary drift potential, EPA considered whether an omni-directional approach to establishing an effects distance (contributing to action area and mitigative buffers) was necessary to account for herbicide transport from the field for time periods following the application.

The only study reporting 5% plant height effects from primary and secondary drift beyond 33.5 m is the Norsworthy 2017 study, which had a transect reporting plant height impacts out to 55 m. However, the average distance for this study was 24 m.

Additional information on other factors influencing the potential for off-site vapor drift is discussed in **Appendix H**.

4.4.5

4.5 Distributional approach to establishing an action area off-field distance.

EPA's routine exposure estimation methods for assessing the potential for effects to listed species involves the use of a reasonable upper bound estimate for establishing exposure levels. This approach is used for exposure estimation in 1) aquatic phase organisms using the PWC model and 2) refined spray drift exposure for terrestrial and aquatic organisms using the AgDRIFT model. In addition, previous effects determinations for dicamba used a reasonable upper bound estimate for volatile drift exposure for using the PERFUM model. For the current effects determination, considering both spray drift and volatile drift exposure to terrestrial plants in the off-site areas, EPA has explored the establishment of a reasonable upper bound estimate for the distance from the field using a distributional approach combining the effects to distance data for all the available field studies (see **Appendix B**).

The Agency created probability distribution for the following variable and data sets:

1. Distance from the treatment field edge to a point related to direct estimate of 5% height for all field studies reporting height in V stage plants.
2. Distance from the treatment field edge to a point related to direct estimate of 5% height for Engenia field studies reporting height in V stage plants.
3. Distance from the treatment field edge to a point related to direct estimate of 5% height for Xtendimax field studies reporting height in V stage plants.
4. Distances evaluated for the VSI approach for height and yield approximation are provided in **Appendix A**.

EPA used Crystal Ball add-in software to Excel to fit distribution functions to the data sets. Crystal Ball enables the user to fit various probability distribution functions to a data set and then sample those distributions thousands of times using Monte Carlo probabilistic algorithms to test the extent to which the selected distributions tend to over or underestimate any segment of the distribution of the variable. Because EPA is interested in reasonable upper bound estimates for the purposes of the effects determination distance to effects analysis, the Agency selected a distribution to fit to the data that would be a more accurate representation of the dispersion of data at the upper limits of the distribution. In the case of the height measurement distributions, the number of available data points was too limited for Crystal Ball to directly fit a distribution (Crystal Ball requires at least 15 discrete values for its software to operate). In those cases, EPA first looked at the summary statistics of the data sets to confirm the comparison of mean and median estimates were sufficiently shifted to suggest a non-normal distribution, and then fit a log normal distribution to the data sets using the mean and standard deviation of the data set as the fitment parameters.

EPA then tested the predictive quality of the distributions by sampling the distributions using Crystal Ball's Monte Carlo random sampling algorithms (random seed, Monte Carlo sampling). EPA then compared the upper quantiles of the data, the fit distribution, and the distribution of randomly sampled values to see if the results produced inconsistent upper quantile values (70%, 80% and 90%). The fitment was considered reasonable if the comparison of the data, the fit distribution and the distribution of randomly sampled values were consistent.

Appendix C provides the Crystal Ball output for each distribution. Good agreement between data, fit distribution, and resampled distribution was found in all cases up through the 90th percentile. **Table 7** below summarizes the findings of the height-based evaluations of distance to effects.

Table 7. Distances (m) to 5% Plant Height Reduction Effect for Dicamba Products

Percentile	All products (n=15)	Engenia (n=4)	Xtendimax (n=11)
95%	17.45	47.89	7.47
90%	15.06	39.60	6.71
85%	13.62	34.85	6.21
80%	12.57	31.50	5.86

75%	11.76	29.10	5.56
70%	11.11	26.99	5.32
65%	10.52	25.24	5.09
60%	9.99	23.61	4.88
55%	9.53	22.15	4.70
50%	9.09	20.78	4.53
45%	8.65	19.48	4.37
40%	8.22	18.29	4.20
35%	7.82	17.15	4.03
30%	7.43	16.01	3.86
25%	7.05	14.88	3.68
20%	6.60	13.72	3.48
15%	6.11	12.50	3.26
10%	5.53	11.09	3.02
5%	4.79	9.29	2.71
0%	2.10	3.21	1.39

4.6. Uncertainties Associated with Establishment of Distances to Effect

Below is a list of uncertainties associated with the plant effects studies and field studies assessed by EPA:

1. The field studies only measured plant height and visual signs of injury. While this is appropriate for studies of V stage plants, for studies with R stage plants, yield is the more appropriate measure. There were no studies that assessed yield. While this does not impact those studies that were conducted at the vegetative growth stage, there is no corresponding apical endpoint for consideration for those studies conducted at the reproductive stage. Therefore, there is some uncertainty as to whether the measures being relied upon will be effective at protecting plants in the reproductive stage.
2. Plant height measurements were provided for a limited number of studies (n=4), three of which were conducted using Xtendimax and one conducted with Engenia, with plant height effects evaluated using soybeans. As such, there is statistical uncertainty in whether this limited number of studies is sufficiently robust enough to reflect potential variance in the effects to plant height in the field.
3. Only one study (Norsworthy 2018) provided measurements that was in some direction other than downwind from treatment, where the downwind direction was established at the time of application. Therefore, measures of effects from volatile emissions are limited to the downwind and upwind transects.
4. Effects on plants in the field studies only used soybeans for evaluation. While soybeans are considered the most sensitive plant, based on laboratory studies submitted to the Agency, there is uncertainty as to how representative these results are for other plant species with different growth and reproduction strategies. This is an inherent uncertainty for all surrogate species-based risk assessments

5. As the volatility of dicamba increases with temperature, particularly above 90°F, there is uncertainty in the field study results as only 3 studies (MRIDs 50578902, 50606801, and 50642801) had sustained temperatures during the day above 90°F. However, the studies were representative of the warmer temperatures experienced in the areas growing soybeans and using dicamba OTT products.
6. Only one study reported the pH of the tank mixture (MRID 50642801). As a result, there is uncertainty as to how the various tank mixtures in the field studies may have had depressed pH values, resulting in increased volatility.
7. A limited number of large field studies were conducted using Engenia. Therefore, there is some uncertainty as to how representative the large field studies conducted using Xtendimax are for Engenia applications.
8. Field studies were conducted primarily in areas with high levels of alleged incidents. As a result, there is uncertainty in whether the results from these studies can robustly account for the variability of dicamba movement and attendant effects for non-target species located across other landscapes proximal to sites of dicamba use.

4.7 Final Selection of off-field distance necessary to establish the limits of the action area.

EPA considered a variety of lines of evidence when determining the appropriate reasonable distance for defining the action area and what, if any, risk mitigation was necessary for this federal action to make no effects for any overlap of action area and listed species. This action involves the consideration of an application to amend the current registrations of dicamba products for the over-the-top use on cotton and soybean genetically modified to be resistant to dicamba to extend the registration to December 20, 2020 as well as include further labeling and registration restrictions as discussed earlier in this assessment to avoid overlapping with listed species locations and critical habitat. These analyses and the addition of terms to the registration, in combination, allow EPA to make no effects determinations for the species of concern.

EPA considered different approaches for making effects determinations. EPA considered existing guidance set forth in the Overview Document related to consideration of effects measurement endpoints that are not direct measurements of survival, growth or reproduction in effects determinations when provided a plausible and quantifiable expression of the relationship between the measurement endpoint and endpoints related to survival, growth or reproduction is established (USEPA 2004, 2015). EPA also considered the Agency's guidance on the use the 5% effect endpoint (EC_{05}) for growth measures (*e.g*. height) in situations where no observed adverse effects concentrations cannot be established for plants because of study design and performance limitations (USEPA, 2011).

Applying the policies discussed above, two types of methodologies were considered to determine how to establish distances to a threshold for plant effects given the best available data for defining the action area:

1. Direct Field Study Approach (discussed in this section): Direct field chemical drift studies that involve measurements of effects on plant height at 21 or 28 days after treatment or plant yield. These measurements directly inform the endpoints related to survival, growth and reproduction.

2. VSI approach (discussed in **Appendix A**)

<u>Considerations of the Direct Field Study Measures Approach</u>

Although the studies are limited, there is confidence in the direct measurements of height effects themselves. The measurements are the product of replicate sampling and are the objective measurement of an endpoint directly applicable to the effects determination, consistent with guidance laid out in the Overview Document (USEPA, 2004).

Additionally, using direct measurements of the height endpoint is preferred to a more complicated and potentially uncertain mathematical relationship, *e.g.,* scoring levels of VSI and applying a relationship factor to approximate a threshold for height effects as was performed in the VSI approach discussed in a subsequent section.

The data set for reliable measures of any reduction in plant height in response to dicamba exposure is limited in number of studies (which affects the ability to represent a variety of conditions), number of transects (which affects the ability to capture or describe the distribution of possible outcomes directionally or omnidirectionally), and the geographical areas of investigation. There is one study available to measure plant height with the formulation Engenia and it looked at a total of four transects. For Xtendimax, there are three studies available constituting eight transects in all. In some cases (*e.g.* Sprague, Young using Xtendimax), the available transect data did not extend in sufficient directions from the treated field to cover any possible volatile dicamba deposition occurring at time periods after the initial spray of dicamba. Although having direct measurements of plant height is very informative (particularly for plants in vegetative growth stages), there is uncertainty because this approach does not provide for an evaluation of effects on plant reproduction through consideration of effects on yield.

EPA intends to establish a reasonable distance to effect for the purposes of establishing an action area which is reasonably protective of listed plant species. Therefore, the analysis considered the number and distribution of the studies into consideration when establishing a distance to effect with this method.

EPA considered the distribution of the total available transect predicted distances to the 5% height effect for all formulations, as well as distributions segregated by formulation. EPA focused on the all-formulation distribution because the distributions for each formulation had too few measurements to be reliable.

Accounting for the small number of studies and limited geographic distribution, EPA elected to evaluate the distribution of the direct measurement approach distances at the 95%-tile to calculate a reasonable and protective distance to the 5% effects threshold. The 95%-tile corresponds to a distance of 57 feet for determining the action area.

Further Consideration of Spray and Vapor Drift

EPA notes that the results of some field studies indicate that vapor drift can be a contributing factor to overall off-field plant exposure. In fact, one of the primary reasons for performing the new effects determination was the fact that previous determinations considered spray drift and volatile drift, separately. In the interest of providing reasonably protective effects determination and for establishing a reasonable exposure mitigation measure for the dicamba products in areas where proximity to listed species is a concern, EPA concludes that the 17.5 m (57 ft) distance to effects threshold be appropriately considered omnidirectional, not just downwind from the treatment site at the time of application. Additionally, the 110 ft downwind buffer is retained to protect from primary drift.

Setting the Action Area Distance.

With a distance for plant effects established at 57 feet, EPA next determined how this distance would be used in setting the limits of the action area beyond the treated cotton or soybean fields. This is then used to determine the degree of overlap with listed species ranges. While the effects distance of 57 feet is the predicted zone of effects beyond the treated fields, EPA understands that the geographical information of species and use-site information is limited to a spatial resolution of 30 m Therefore, the action area for this federal action is the cotton and soybean fields in states of proposed use extended outward by 30 m in all directions. This is a conservative representation of the action area limited by data resolution and EPA expects that it will serve to include more species ranges in the overlap analysis with the action area.

Using the 57 feet Distance as Risk Mitigation

The 57 feet off-field distance to plant effects can be used to mitigate risk to listed species. This risk reduction can occur using 57 feet as a no spray buffer within the treat field. This buffer, when applied omnidirectionally to treated fields 57 feet or less distant from sensitive areas within listed species ranges and in combination with the retention of the 110 foot in-field wind-directional spray drift buffer already on the registered labels, serves to limit the dicamba effects zone to an area within the treated field in those selected areas of dicamba use. Where the best available information for a listed species indicates that it would not occur on a treated field, this mitigation would place the effects border outside of the listed species' range, achieving a No Effects determination.

5. Establishing the Action Area and Making Effects Determinations

5.1 Background

Previous effects determinations (USEPA, 2016c-e,i) concluded that, with selected mitigations in place (*e.g.* 110- foot wind-directional buffer at the time of application), concern for listed species effects from the uses of Xtendimax and Engenia on dicamba-tolerant (DT) cotton and soybean fields were limited to the confines of the treated fields themselves (*i.e.,* the action area was the treated field, itself). New information that is now available, including FIFRA 6(a)(2) reporting, state agricultural investigative reports and media reporting, appear to show that dicamba emission ((through spray drift, volatile drift, or a combination) from the use of these registrations on DT-cotton and soybean fields has resulted in effects to non-target terrestrial plants offsite from the treated fields. This new information demonstrated the need to reevaluate the 2016 Endangered Species Act (ESA) effects determinations involving Federally listed threatened or endangered terrestrial plants for any new regulatory decision involving the use of these registrations on DT-cotton and soybean fields.

In establishing the action area and completing this effects determination, EPA considered the following information:

1. The analysis of available laboratory and field volatility and effects data summarized in earlier sections of this document (see **Sections 4.1-4.5** above).
2. The suite of general and proposed specific label statements and requirements intended to reduce off-field transport of dicamba (discussed immediately below).
3. EPA determination that 57 feet is the appropriate buffer (see **Section 4.7** above)

<u>Suite of general and proposed specific label statements and requirements</u>
In addition to the retention of the 110-foot downwind spray drift buffer currently on the Engenia, Xtendimax, and FeXapan labels, which was an important component of earlier no effect determinations, the new labels will have the following general label requirements (for use in all states):

1. Restriction for use by certified applicators only (intended to improve label compliance).
2. Require dicamba specific training for all applicators (intended to improve label compliance).
3. Label language revision to improved label consistency and enforceability (intended to improve label compliance).
4. Revised language limiting dicamba application to an interval between 1 hour after sunrise and 1 hour before sunset (intended to reduce the potential for applications proximal to inversion conditions).
5. Establishing the period of application limited to 45 days after soybean planting (or before R1 stage) and 60 days after cotton planting (limiting the extent of the growing season where dicamba is applied and potentially reducing applications during periods of high temperature).

6. Tank clean out instructions to include clean out of the entire application equipment (intended to reduce the potential for cross-contamination).
7. Improve label description of sensitive crop/susceptible crop and sensitive areas (intended to improve label compliance and reduce the potential for dicamba application near sensitive non-target plants).
8. Enhance the label with pH advisory language to improve applicator awareness of the impact of low tank-mix pH on volatility of dicamba (expected to reduce the contribution of volatile dicamba to overall off-site exposure).

The above general label requirements are reasonably expected to improve pesticide applicator awareness by instructing them in methods expected to reduce dicamba movement potential and to further minimize the potential for off-site dicamba movement.

In addition to the general label requirements listed above this effects determination will evaluate the changes to species effects determinations as a result of additional label requirements to address potential effects to federally listed threatened and endangered species. These include:

1. Generic Bulletins Live! statement on the product label directing applicators to consult the Bulletins Live! application for additional application instructions for their intended location for dicamba application. These include:

   > "It is a Federal offense to use any pesticide in a manner that results in the death of an endangered species. Use of this product may pose a hazard to endangered or threatened species. When using this product, you must follow the measures contained in the Endangered Species Protection Bulletin for the area in which you are applying the product. To obtain Bulletins, no more than six months before using this product, consult http://www.epa.gov/espp/ or call 1-844-447-3813. You must use the Bulletin valid for the month in which you will apply the product."

2. In areas pertinent to the Bulletins Live! instructions the applicator will be instructed to establish an additional omnidirectional in-field buffer of 57 feet from identified sensitive areas in addition to the wind directional 110-foot buffer.
3. Prohibition of dicamba application in areas where a federally listed threatened or endangered non-monocot plant may reasonably be expected to occur on treated fields (a scenario where elimination of concerns for plants effects off the field is insufficient to protect individuals of the species on the field).

5.2 Establishing the Geographic Extent

EPA established the geographic extent of the potential action area using the for expected terrestrial plant effects combined with multi-year aggregate (2010-2016) of the Cropland Data Layer (CDL) information into Use Data Layers (UDL) for the 34 labeled states for dicamba uses on GMO cotton and soybean (AL, AZ, AR, CO, DE, FL, GA, IL, IA, IN, KS, KY, LA, MD, MI, MN, MS, MO, NE, NM, NJ, NY, NC, ND, OH, OK, PA, SC, SD, TN, TX, VA, WV, WI).

The UDL data layer was extended outwards 30 m (98 feet) in all directions to incorporate the off-site distance of 57 feet or a minimum resolution distance for species action area overlap, whichever is greater. As discussed in the uncertainties section above, the resolution of the UDLs is 30 m and distances below 30 m cannot accurately be calculated. As discussed in the uncertainties section below, the resolution of the UDLs is 30 m and distances below 30 m cannot accurately be calculated. Use of this 30-m buffer on the UDLs sets a conservative boundary to the action area. This action area, without any further label mitigation measures, is then compared with range and critical habitat information for listed species. The spatial analysis makes conservative assumptions related to extent and distribution to be protective of the species when assessing the relationship of the species range to the action areas; the impacts of the uncertainties in data are discussed in more detail in the uncertainty section.

5.3. Listed Species of Concern Within the Action Area

The action area has been set considering the established most sensitive plant, soybean, a dicot plant. The available terrestrial plant data set indicates that the dicot plant species are generally more sensitive than monocots, and that the most sensitive dicot, soybean, is substantially more sensitive than the most sensitive monocot, onion (DP Barcode 378444). Given the already protective nature of the existing in-field buffers for monocots, and the far lower sensitivity of the most sensitive monocots compared to the most sensitive dicots (most sensitive monocot is four orders of magnitude less sensitive than the most sensitive dicot, DP Barcode 378444), it is reasonable to exclude listed monocot plants from further effects determination efforts because there is no evidence to suggest exposure off treated fields will be sufficient to trigger monocot concerns. Moreover, DP Barcode 378444 demonstrates, even without in-field buffers, off field movement was below the NOEC for the most sensitive monocot plants a scant 7 feet from the field edge with non-conservative drift estimates. This distance is within the margin of error for any overlap analysis and is essentially equivalent a treated field itself.

With an action area conservatively established, EPA compared this geographic area with the known listed terrestrial plant species range map information (USFWS, 2017). First, all species with greater than 1% overlap[3] of a species range with the action area were identified. Next, all counties with a species from the first step and greater than 1% overlap with the action area in the county were established as the area where overlap is reasonably certain to occur. The species meeting these conditions are found inside the action and identified as “may affect”. Species are considered to be outside the action area and “no effect” if these conditions are not met after accounting for significant digits.

[3] EPA has used this 1% overlap criteria because a known source of error within spatial datasets is positional accuracy and precision. The National Standard for Spatial Data Accuracy outlines the accepted method for calculating the horizontal accuracy of a spatial dataset (FGDC, 1998). To prevent false precision when calculating area and the percent overlap, only two significant digits should be considered for decision purposes given the reported 60 meters of horizontal accuracy for the CDL.

A list of all of the additional species of concern (non-monocot plants) within the expanded action area (treated field + 30 m spatial buffer to estimate the 57-foot buffer is provided in **Appendix D**, including the effects determination with no modification of the federal action for each species. EPA also analyzed whether any additional animal species beyond those previously assessed could now be present on the treated field. EPA compared the list of previously assessed species by comparing scientific name and/or species entity id to an updated table of listed species addressing slight variations on scientific name due to updates or multiple populations. With no modification of the federal action, 69 listed dicot plant species were found to be within the action area. If a 57-foot omnidirectional in-field buffer (in addition to the 110-foot wind directional in-field spray drift buffer already on the label) were to be imposed as a label mitigation, then all but one species would be excluded from the action area (*i.e.* the action area would be limited to the treated field). The remaining species is the spring creek bladderpod (*Lesquerella perforata*), endemic to Wilson County, TN. County exclusions are already specified on the label for Wilson County, TN. No additional animal species were found to overlap with the treated field.

5.4 Uncertainties Associated with the Spatial Analysis

The overlap analysis was based on the species location provided by the US Fish and Wildlife Service (USFWS, 2017). Species range is defined as the geographical area where a species could be found in its lifetime. Produced and managed by the species experts with jurisdiction of the Endangered Species Act (ESA) these data are the best available information for species range, however, there are several uncertainties worth noting. The range information is not sub-divided into additional qualifiers such as current/historical locations or temporal information to account for distribution variations relating to timing such as seasons. Without additional distribution information, EPA applies certain additional conservatisms: specifically, a uniform distribution within the range is assumed, meaning the species is assumed to be present in all sections of the range at all times of the year. Further, this distribution assumption is applied to full extent of the species range, which is an additional conservatism because this distribution is unlikely to actually occur based a species life history. Other sources of species range information, such as NatureServe, indicated more refined extents for range based on known observations for a species. However, these surveys are not exhaustive, and therefore only indicated known species locations.

Other commonly known and related sources of uncertainty for GIS data generally are related to accuracy and precision. Accuracy can be defined as how well information on a map matches the values in the real world. Precision relates to how well the description of the data matches reality, based on closeness of repeated sets of measurements. Some sources of inaccuracy and imprecision in GIS data are obvious while others are difficult to identify. It is important to consider these sources of error as GIS software can make users think data is accurate and precise beyond the limits of the data. When conducting this spatial analysis to assess the relationship between the species range and agricultural locations conservative assumptions are made related to the accuracy and precision of the available data. These assumptions impact the uncertainty of the relationship, and in most cases potentially overestimate the relationship between of species range and agricultural locations.

To address classification accuracy and positional accuracy of the agricultural GIS data used by EPA, multiple years were combined into a Use Data Layer (UDL) for a crop to represent anywhere the crop could be found. However, this is likely an overestimate of where a crop is found in any given year due to common agricultural practices such as rotation. Data resolution or the smallest difference between features that could be recorded is related to accuracy. The raster land cover data used to identify agricultural land, the Cropland data layer (CDL) produced by United States Department of Agriculture (USDA), has a resolution of 30 meters. A raster data set can be re-sampled into small increments but this does not improve the resolution or accuracy of the dataset. For this reason, values falling between the resolution value cannot accurately be determined and distances below 30 meters cannot be calculated.

Common sources precision errors can be introduced when formatting data for processing. Formatting changes can include changes to scale, reprojections of data, and data format conversions (raster to vector or vice versa). Sources of errors that are not as obvious can include those originating from the initial measurements, digitizing of data, and using different versions of a dataset. These types of precision error may introduce edge effect, or misaligned dataset when conducting the spatial analysis. Borders following the general shape of the county boundaries but do not align exactly in range information used could be result of this type of precision error.

These uncertainties impact the relationship between the agricultural areas and species locations. The spatial analysis makes conservative assumptions to err on the side of the species when assessing the relationship of the species range to agricultural land. This relationship may be overestimated when the range is larger than the actual area occupied and the additional area includes agricultural use or where edge effects were introduced. County or state boundaries can be used as a conservative estimate for species range but species and natural habitats are not expected to follow man-made boundaries, which will include agricultural lands. Underestimates of the relationship between species range and agricultural use can occur if the range represents a large area but the species occupies a refined area adjacent to agricultural land. In this situation, the conservative species boundaries may dilute the relationship. While this underestimation is possible, the additional conservative assumptions for agricultural land UDLs and the use of the best available information as defined by the species experts attempts to minimize this possibility.

5.5 Effects Determinations and the Impact of Modifications to the Federal Action

For each species with range overlap within the action area (**Appendix D**), EPA made an effects determination for each of three scenarios. The results of these effects determinations are provided in **Appendix D**.

Under Scenario 1, the effects determination is based on the federal action as initially described in Section 1.0 of this document. No mitigations beyond that which is described in Section 1.0 were considered. If the species overlap analysis places portions of the species range within the action area, it is conservatively presumed that individuals of the species within that overlap area are, according to the best information available, reasonably expected to be affected by the federal action (May Affect).

With Scenario 2, EPA assumes that the federal action is modified to require the EPA established 57-foot omnidirectional in addition to the retained 110-foot spray drift buffer in the direction of the wind in-field application offset buffer in areas proximate to the locations of species overlap (at the county or subcounty level of resolution). The in-field buffer is intended to move the boundary of the action area away from the locations of species overlap, back toward the treated field boundary. This avoids overlap of the listed species' range with the area where effects to plants are reasonably expected to occur. By using this buffer mitigation to eliminate overlap of the species with the action area, EPA can confidently determine the action as modified will have no effect on listed species (No Effect). The spatial data layer used for the action area has a resolution of 30 m, therefore a 30-m buffer was used in the spatial analysis to estimate the 57-foot buffer. Appendix C reflects the changes in effects determinations as a result of this modification to the federal action.

Finally, Scenario 3 applies to species where overlap with the action area includes expected occurrence of the species on the treated cotton or soybean fields themselves. In these circumstances, a buffer designed to limit dicamba exposure to the margin of the treated field is insufficient to preclude effects to individuals of the species that might occur within the treated cotton or soybean field. Therefore, this scenario includes an additional mitigation that modifies the federal action with a labeled zone where dicamba application in prohibited. This prohibition zone may either be at the county level of resolution or at a sub-county level, where best available information provides more refined spatial resolution. By removing that area from dicamba application altogether, EPA can confidently determine that individuals of the species will not be affected by the federal action (No Effect).

Initially, the spatial extent of the modification is set based on location files provided by USFWS in 2017 and the results of the overlap analysis. If the location file is at the county level, the modification/limitation extent will follow the county boundary, if sub-county sections are present, the extent of the modification/limitation with follow the sub-county boundary with a buffer of 57 feet, see column 'Counties with overlap' of **Appendix D**. The final spatial extent of the modification/limitation may change under the following conditions.

- Updated information related to counties within the species range documented in the publicly available spatial files in ECOS; remaining counties found in column 'Accounting for ECOS updates'.

5.6 Critical Habitat Determinations

In addition to the species-specific effects determinations discussed above in Section 6, EPA also conducted the same overlap analysis to the critical habitat map information and identified new critical habitat within the expanded action area for listed terrestrial species as described in Section 6 (USFWS, 2017). Critical habitat with less than 1% overlap after accounting significant digits are outside the actions and not considered further, critical habitat greater than 1% overlap are inside the action area and the modification analysis conducted. The critical habitat modification analysis is based on an assessment of how dicamba DGA and/or BAPMA salts would affect the U.S. Fish and Wildlife Service or National Marine Fisheries Service (the Services) established principle constituent elements (PCE's) of the designated habitat as well as how direct species effects outcomes would impact critical habitat's present and future utility for promoting the conservation of a particular listed species. The Agency will conclude "modification" of designated critical habitat based on the results of the overlap analysis for the available critical habitat maps found in the states subject to the Federal action and one or more of the following conditions exist:

1. The available Services' information indicates that cotton or soybean fields or areas within 30 meters (spatial estimate of the EPA established 57-foot buffer) of these fields are habitat for the species and there is a "may affect" determination for the species associated with exposure to dicamba DGA/BAPMA salts or the degradate, DCSA, as labeled.

2. The available Services' information indicates that the species uses cotton or soybean fields or non-monocot species within X meters of these fields and one or more effects on taxonomic groups predicted for dicamba DGA/BAPMA salts or the degradate DCSA, on cotton and soybean fields would modify one or more of the designated PCEs.

If neither of the above conditions are met, EPA concludes "no modification."

The list of species with critical habitats and the attendant determinations of modification for all of the additional terrestrial critical habitats of concern within the expanded action area (treated field + 30-meter spatial buffer to approximate the 57-foot buffer) are presented in **Appendix E**. Designated critical habitats for 14 species were found to be co-located with the action area described as treated cotton and soybean fields with an additional omnidirectional 30 m boundary. 12 of these critical habitats would be "Modification" with no additional mitigation and 2 critical habitats would be "No Modification" by virtue of not having PCEs related to non-monocot plant species. With the imposition of a 17.5 m (57 feet) omnidirectional in-field buffer (in addition to the already labeled 110-foot wind directional spray drift in-field buffer), then all critical habitats would be excluded from the action area.

The spatial extent of the modification for critical habitat will be set based on location files provided by USFWS in 2017 and the results of the overlap analysis.

6. Summary

Previous effects determinations concluded that, with selected mitigations in place (*e.g.* 110-foot wind-directional buffer at the time of application), concern for listed species effects from the uses of Xtendimax, FeXapan and Engenia on dicamba-tolerant (DT) cotton and soybean fields were limited to the confines of the treated fields themselves (*i.e.,* the action area was the treated field, itself). New information that is now available, including FIFRA 6(a)(2) reporting, state agricultural investigative reports and media reporting, appear to show that dicamba emission ((through spray drift, volatile drift, or a combination) from the use of these registrations on DT-cotton and soybean fields has resulted in effects to non-target terrestrial plants offsite from the treated fields. This new information demonstrated the need to reevaluate the 2016 Endangered Species Act (ESA) effects determinations involving Federally listed threatened or endangered terrestrial plants for any new regulatory decision involving the use of these registrations on DT-cotton and soybean fields.

EPA evaluated new data, including field volatility and vapor exposure toxicity studies submitted by the registrants and large field studies conducted by academic researchers. Additionally, as much of the incident and some of the field study data described effects solely in terms of visual signs of damage, rather than effects to apical endpoints such as plant height and yield, EPA considered open literature data relating visual signs of damage to these apical endpoints.

EPA concluded that the new information supported the need for an additional in-field 57-foot omnidirectional buffer in areas where listed dicot plant species are present to support the previous No Effect calls. This buffer determination was based on a distributional approach combining the direct effects (based on the most sensitive endpoint of plant height) to distance data for all the available field studies. Accounting for the small number of studies and limited geographic distribution, EPA decided to evaluate the distribution of the direct measurement approach distances at the 95%-tile to calculate a reasonable and protective distance to the 5% apical effects threshold.

EPA established the geographic extent of the potential action area using the for expected terrestrial plant effects into Use Data Layers (UDL) for all of the 34 labeled states for dicamba uses on GMO cotton and soybean. The UDL data layer was extended outwards 30 meters in all directions to incorporate the off-site distance of 57 feet or a minimum resolution distance for species action area overlap, whichever is greater. This area was then compared with the geographic area for the known listed terrestrial plant species ranges and all counties with a species with greater than 1% overlap with the action area in the county were established as within the action area and identified as “may affect.”

Of the 69 listed species co-located with the action area described as treated cotton and soybean fields with an additional omnidirectional 30-meter boundary;

1. 69 species would be may-affect with no additional mitigation,
2. 1 species (the spring creek bladderpod) would be May Affect and 68 species would be No Effect with the imposition of a 57-foot omnidirectional in-field buffer and
3. all 69 species would be No Effects with the imposition of the 57-foot buffer and the continued labeled county prohibition for Wilson County, Tennessee (for the endemic spring creek bladderpod)

Of the 14 designated critical habitats co-located with the action area described as treated cotton and soybean fields with an additional omnidirectional 30-meter boundary;

1. 12 critical habitats would be "Modification" with no additional mitigation and 2 critical habitats would be "No Modification" by virtue of not having PCEs related to non-monocot plant species
2. 14 critical habitats would be "No Modification" with the imposition of a 57-foot omnidirectional in-field buffer

These effects determinations, critical habitat modifications, and mitigation measures have considered the uncertainties in the analysis as noted throughout the document. These included, but are not limited to interpreting the incident data (largely due to the nature of incident observations being limited to visual signs of injury), field study limitations (*e.g.* varying environmental conditions in field studies, nature of subjectivity in VSI estimates between different observers, etc.), and geospatial analysis (*e.g.* species are presumed to be distributed throughout their range at all times of the year).

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Appendix A. Relating Visual Signs of Injury to Apical Endpoints

As discussed above in **Section 3.1**, EPA typically considers direct effects to apical endpoints (survival, growth and reproduction) to assess risks to aquatic and terrestrial organisms. EPA routinely considers information in the open literature when determining endpoints for risk assessment. A number of dicamba field effects studies present results in terms of measurements of visual signs of injury. EPA commonly uses effects endpoints in effects determinations that consist of measures of plant growth. While these measurement endpoints are routinely used to calculate the risk quotients that support effects determinations, generally EPA has taken the position that they do not represent a limitation on the types of toxicity endpoints that may be considered (USEPA 2004, https://www.epa.gov/sites/production/files/2014-11/documents/ecorisk-overview.pdf). The assessor may encounter other effects data that provide insight on endpoints not routinely considered for calculation; professional judgment is used and documented by the assessor to determine whether and how available data on other toxicological endpoints are included in the risk assessment. Following the recommendations of the National Academy of Sciences, EPA released a document on interim approaches for national-level pesticide endangered species act assessments (USEPA 2015, https://www.epa.gov/sites/production/files/2015-07/documents/interagency.pdf) that provides useful guidance on applying professional judgement to the utilization of other effects endpoints. The interim approach states "For plants, endpoints that can be quantitatively or strongly qualitatively linked to effects on growth, the level corresponding to a reproduction/growth no observed adverse effect concentration or level (i.e., NOAEC/NOAEL) for the most sensitive species will be used."

Many of the available field studies investigating plant response to off-field dicamba exposure report visual signs of injury (VSI), with many studies sharing the same protocol and recommended scoring system, as the only measurement endpoint for the study. EPA investigated multiple lines of evidence to inform a policy decision regarding the use of such information in this effects determination. The lines of evidence included:

- the dicamba herbicidal mechanism and whether VSI and height or yield effects are grounded in a common biologically relevant mechanism;
- the biological implications of growth stage of tested plants and the reasonableness of establishing relationships of VSI to other effects; and
- an evaluation of VSI observations relative to observations of height and yield effects in dose:response studies to explore the potential for establishing a quantitative link between VSI and height or yield effects.

The discussion below describes the VSI data and analysis. While informative, EPA has chosen to rely on measurements of plant height because these are direct measures of apical endpoints. This avoids the establishment of mathematical relationships between other endpoints (*e.g.* VSI and plant height or yield). The use of plant height data eliminates the uncertainty associated with the subjective nature of VSI measurements. However, as with all limited field study data, relying on the plant height data from four field studies has uncertainties related to study conduct as well as geographical and environmental variability.

A.1 Considering the Dicamba Herbicidal Mechanism

EPA evaluated whether there is a plausible mechanistic link between VSI responses and impacts on growth or yield. Dicamba is an auxin (indole-3-acetic acid) mimicking compound (Kelley and Riechers 2007). Auxin governs dynamic cellular processes involved at several stages of plant growth and development and dicamba is a benzoate auxin herbicide that acts by mimicking indole-3-acetic acid. Although the precise mechanism of action of auxin herbicides is not fully understood, the mechanism appears to involve a stimulation of ethylene production leading to an accumulation of abscisic acid and/or cyanide resulting in abnormal growth. At sufficiently high levels of exposure, the abnormal growth is so severe that vital functions cannot be maintained and the plant dies. The differential toxicity of dicamba to various plant species is based on variations in the ability of different plants to absorb, translocate, and degrade the herbicide. The mode of action—the induction of hormonal imbalance—is specific to plants and does not affect animals (USDA, 2004; available at: https://www.fs.fed.us/foresthealth/pesticide/pdfs/112404_dicamba.pdf

The most typical injury symptom of dicamba is epinasty, or curved and twisted stems and leaves. This is one of the primary symptoms observed and used when scoring visual signs in injury. Derr et al. (no publication data , http://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/PPWS/PPWS-77/PPWS-77P-pdf.pdf) suggests this abnormal growth is caused by the auxin-mimicking effect of the herbicide stimulating growth on different sides of an organ. In addition, dicamba injury is also manifested in the form of meristematic inhibition. This is also a symptom used for injury scoring, where leaf edge meristems are inhibited by dicamba, and often force the leaf to form a cup-shape. This cupping is often associated with a darker green color and a bunched, or puckered, appearance (Iowa State University, no date, http://agron-www.agron.iastate.edu/~weeds/Ag317/manage/herbicide/dicamba.html and Cornell University, no, date https://weedecology.css.cornell.edu/herbicide/herbicide.php?id=2).

In summation, the mechanism that causes epinasty and meristematic inhibition, rapid abnormal growth through the auxin-like characteristics of dicamba, is the same mechanism that ultimately disrupts the nutrient flow of the plant leading to reduced growth and ultimate starvation.

A.2 Considering the Biology of Growth Stage

An important aspect of establishing relationships of visual signs of injury to height or yield effects is to consider the sensitivity of height and yield measures with respect to growth stage of the tested plant species. While it is important to realize that this effects determination is using soybeans as a sensitive surrogate plant to represent other non-monocot plants with varied schedules for growth and reproduction, it is also important to understand the limits of the empirical designs of studies as they relate to growth stages of soybeans. Field effects studies with soybeans are typically conducted using plants in either vegetative growth stage or reproductive stage. In vegetative growth stages, the tested soybean plants are actively producing more vegetative mass and actively increasing in overall height. The vegetative phase involves exponential increase in biomass (Peterson 2007). As the soybean plants enter reproductive stages, energy is diverted from the production of vegetative mass to production of reproductive structures and offspring and the increase in biomass now takes on a linear rate (Peterson 2007). This shift in energy allocations would suggest that measures of height effects on plants are likely to be more pronounced when exposures occur during the vegetative growth states of the plants, and that effects on yield are likely more pronounced when the plants are shifting to reproductive development. Therefore, the concentration that causes a 5% reduction in plant height or yield would be lowest within the most sensitive growth stages for each. Because plant injury isn't linked to these same shifts in plant growth stages, the relationship of injury does not markedly change and thus the concentrations required to impart a relative level of injury to the plant do not significantly change based on growth stage either. Consequently, establishing relationships between visual injury and plant height effects are best performed using plants in vegetative (V) growth phases while visual signs of injury related to yield relationships are best investigated with plants in the reproductive (R) stages.

Several available field studies of dicamba effects to non-target plants only measure the extent of VSI against either the distance from a treated plot or to a received dose of dicamba.

A.3 Evaluation of the Available VSI to Height and/or Yield Relationship Studies

Brief discussions of the studies reviewed for estimating the VSI to height or yield are provided below. The estimated ratios are presented in **Table A.1**. The Excel file titled (Open Literature Evaluations 10-26-18.xlsx, found on the docket) provides the calculations and equations for each of the ratio estimates.

Kniss (2018, prepublication) provided information related to soybean exposures associated with a 5% yield loss for soybeans. The analysis encompassed 11 primary publications and spanned the years 1978 to 2016. As expected based on the considerations discussed above regarding exposure timing effects on yield, the reproductive phases of soybean exposure were more sensitive than the vegetative phases, with R1 to R2 exposures of 0.15 to 14 g/ha (1.34×10^{-4} to 1.25×10^{-2} lb a.e./A) producing 5% yield loss with an across study pooled mixed model estimate of 5% yield effect value of 0.89 g/ha (7.94×10^{-4} lb a.e./A). This estimate approaches the listed species endpoint used in the effects determinations (0.00026 lb ae/A). Vegetative phases V1 to V3 exhibited 5% yield loss at dicamba exposures ranging from 1.6 to 24 g/ha (1.43×10^{-3} to 2.14×10^{-2} lb a.e./A) with a pooled across study mixed model estimate of 1.9 g/ha. Growth stages V4 to V7 showed 5% yield loss at an exposure ranging from 1.2 g/ha to 47 g/ha (1.07×10^{-3} to 4.19×10^{-2} lb a.e./A) with a pooled across study mixed model estimate of 5.7 g/ha (5.26×10^{-3} lb a.e./A

Silva et al. (2018) was also reviewed to make comparisons of height and yield with visual signs of toxicity. In this field trial, dicamba was directly applied to dicamba sensitive soybean at 0, 3.7, 7.4, 14.9 and 29.8 g a.e./ha. Spray applications were made at the V5 or R2 growth stages in separate experiments. Visible estimates of soybean injury were collected at four weeks after treatment on a 0 to 100% scale relative to untreated plots (method/scale used for injury was not reported). In addition, five random plants in each treatment were selected for soybean height, which measured distance from the ground to the tip of the topmost fully expanded leaf. At harvest, the two center rows of each plot were harvested manually and grain yield (total grain weight) was recorded and normalized to a constant water content. Application rate was regressed against visual injury, height and yields. From these regressions, an estimated dicamba treatment corresponding to a 5% yield reduction at harvest were 3.49 and 1.03 g a.e./ha (3.1 $x10^{-3}$ and 9.2×10^{-4} lb a.e./A, respectively), for dicamba treatment to V5 and R2 growth stage soybean, respectively. The estimated dicamba treatment corresponding to a 5% reduction in plant height was 0.86 and 0.45 g a.e./ha (7.67×10^{-4} and 4.01 $x10^{-4}$ lb a.e./A, respectively) for V5 and R2 growth stages, respectively.

Foster and Griffin 2018, another study reporting field response of soybean to a dose progression of dicamba treatments was also reviewed. This field study evaluated the impact on non-dicamba resistant soybean (three cultivars: Pioneer 94Y80, Terral REV 51R53, and Asgrow 4835, one for each of the three years of the experiment) from direct spraying of dicamba. The dicamba DGA salt (Clarity® herbicide; BASF Corp., Research Triangle Park, NC) was applied to soybean at V3/V4 (third/fourth node with two to three fully expanded trifoliates) or at R1/R2 (open flower at any node on main stem/open flower at one of the two uppermost nodes on main stem). Dicamba rates included 0.6, 1.1, 2.2, 4.4, 8.8, 17.5, 35, 70, 140, and 280 g ae/ha (1/1,000 to 1/2 of the manufacturer's use rate of 560 g/ha). Nonionic surfactant at 0.25% vol/vol was added to all treatments, and a nontreated control was included for comparison. A randomized complete block design with a factorial arrangement of treatments (growth stage by dicamba rate) and four replications were used each year. Plants were evaluated for severity of % injury and percent reduced height at 7 and 15 days after treatment (DAT), mature plant height prior to harvest, and grain yield (moisture adjusted) at harvest. While the manuscript did not provide 5% effect levels, EPA used the equations that were provided in the manuscript to estimate the concentration causing a 5% effect on mature plant height and grain yield (see Open Literature Evaluations 10-26-18.xlsx).

5% Grain Yield Reduction
R1/R2 Exposure = 1.24 g ae/ha (1.11×10^{-3} lb ae/A)

5% Mature Plant Height Reduction
V3/V4 Exposure = 2.02 g ae/ha (1.80×10^{-3} lb ae/A)

These results are consistent with those of Silva et al. (2018) with height being more sensitive following applications during the rapid growth phases (V3/V4) and yield being more sensitive when applications are made during bloom (R1/R2). The resulting 5% effect concentrations are greater than those relied upon in the dicamba risk assessments (regulatory listed species endpoints: 0.34 g ae/ha (0.00030 lb ae/A) for the BAPMA form; MRID 48718015).

Robinson et al. 2013 conducted field experiments at the Dow AgroSciences Midwest Research Center (MRC) near Fowler, IN in 2009. The authors planted Beck's brand '342NRR' soybeans in 38-cm rows at a density of 430,000 seeds/ha. Dicamba (diglycolamine salt) was applied at rates of 0, 0.06, 0.2, 0.6, 1.1, 2.3, 4.5, 9.1, and 22.7 g/ha at V2, V5, or R2 soybean growth stages. The applications were made to plots which were 3.1 m wide and 9.1 m long and consisted of a 3.1-m-long and 1.5-m-wide buffer to reduce the possibility of off-target movement into adjacent plots. All dicamba treatments were applied in 140 L/ha carrier volume using a CO2-pressurized backpack sprayer with a 3.1 m-wide boom and XR11002 flat fan nozzles (TeeJet Spraying Systems Company, Wheaton, IL 60189) at 138 kPa. Wind speeds at application were less than 5 km/h. The authors reported visual estimates of percentage of soybean injury at 14 and 28 DAT using a scale of 0 to 100%, where 0% = no crop injury and 100% = complete plant death (no additional details were provided). Plant height was also reported based on three plants sampled at the R8 growth stage. Additionally, 10 plants from the middle two rows of each treatment were arbitrarily selected to determine the following reproduction endpoints: yield (seed mass g/100 seeds), #seeds/m, #seeds/pod, #pods/m, #main-stem reproductive nodes/m, #pods/reproductive node, #mainstem nodes/m, and percentage of reproductive nodes. Plants were harvested with a plot combine and seed yield was adjusted to 13% moisture. Oil and protein concentrations were determined from machine-harvested seed using near-infrared reflectance spectroscopy at the Purdue University Grain Quality Laboratory.

EPA's review of the study results focused on the plant reported yield effects and their relationship to plant injury. The regression equations provided in Figure 5 of the study provided sufficient information to estimate the VSI to plant yield ratio (**Table A.1**). These results reflect the combination of the study sites presented in the study, however the individual study sites result in similar relationships and support the combined analyses presented. The derived ratio is also within the range of those estimated from the other studies discussed in this section and **Table A.1**.

Growe (2017) also evaluated the effects of sub-lethal rates of dicamba on five maturity group VI soybean cultivars at vegetative and reproductive growth stages. The design was a factorial arrangement of 80 treatments in a randomized complete block with four replications and three factors consisting of dicamba rate, soybean cultivar, and soybean growth stage. Trials were conducted near Kinston, Lewiston, and Rocky Mount, NC. In each trial, five soybean varieties were planted using a two-row cone planter. The DGA salt formulation of dicamba (Clarity) was applied to soybean at 1.1, 2.2, 4.4, 8.8, 17.5, 35, and 70 g/ha (1/512 to 1/8 of the labeled 560 g/ha use rate for weed control in dicamba-tolerant soybean) when soybeans reached V4 (three completely unrolled trifoliates) or R2 (full bloom) growth stages. A non-treated control was included for each variety. Plot dimensions were 3.65 m wide by 9 m long. After each application, effects of dicamba were determined by collecting visual injury ratings at 7, 14, and 28 DAT using a scale of 0 (no injury) to 100% (complete death). Soybean height was recorded 0, 14, and 28 DAT by randomly selecting four plants from each plot and measuring from the soil surface to the terminal bud. The treated rows for each plot were mechanically harvested and yields were adjusted to 13% moisture.

While the manuscript did not provide 5% effect levels, EPA used the equations that were provided in the manuscript to estimate the concentration causing a 5% effect on mature plant height and grain yield.

5% Grain Yield Reduction (based on combined harvest)
Kinston, R2 Exposure = 1.30 g ae/ha (1.16×10^{-3} lb ae/A)
Lewiston, R2 Exposure = 0.90 g ae/ha (8.04×10^{-4} lb ae/A)
Rocky Mount, R2 Exposure = 2.05 g ae/ha (1.83×10^{-3} lb ae/A)

5% Mature Plant Height Reduction
Kinston, V4 Exposure = 0.81 g ae/ha (7.23×10^{-4} lb ae/A)
Lewiston, V4 Exposure = 2.46 g ae/ha (2.20×10^{-3} lb ae/A)
Rocky Mount, V4 Exposure = 0.265 g ae/ha (2.37×10^{-4} lb ae/A)

Growe (2017) also reported results of another dose based study (chapter 2). However, the results of this study were not presented in a format to discern the height data from vegetative stage exposures from those following reproductive stage exposures. Therefore, the chapter 2 results were excluded from further review.

Jones (2018, Chapter 1) evaluated the impact on non-dicamba resistant soybean from nearby dicamba applications, such as those made to nearby dicamba tolerant soybean and cotton in a series of separate but interrelated experiments (presented in separate chapters). Presented in Chapter 1 are the results of twenty-five field experiments conducted in 2014 and 2015 in Keiser and Marianna, Arkansas. These experiments were conducted using Clarity® (BASF Corporation) at 560 g a.e./ha (maximum labeled field rate for over the top application) applied during the reproductive stages of R1 through R6. Plots extended along transects until no injury was observed or the end of the field was reached. Soybean injury and three canopy heights were recorded at 28 DAA for each plot. A visual scale from 0 to 100%, with 100% being plant death, was used to estimate soybean injury (no further details on the visual scale method were provided). The percent of pods malformed and the height to the terminal of three individual plants per plot were recorded at soybean maturity. Additionally, a small-plot combine was used to harvest plots, and grain yields (based on weight) were corrected to 13% moisture before being converted to a percentage yield relative to uninjured plots.

These data were reviewed by EPA to explore the ratio of visual signs of injury (VSI) to percent yield reduction at the 5% threshold. While instances of height reduction (5%) differed among growth stages were reported, the exposure was timed at the R1 through R5 growth stages and thus, height impacts were determined by EPA to be less informative than the yield results. Furthermore, the results for pod malformation and seed germination were not considered further due to their relative insensitivity as compared to yield. Percent Yield reduction and percent injury regression equations, provided by Jones, were used to estimate the corresponding level of visual injury that was observed at the same distance as 5% reduction of yield. This established a ratio of visual injury percentage to 5% reduction in yield. The average ratio for of all trials was 5.1 (0.6-8.8). In other words, for a 5% reduction in yield a 26 % rate of visual injury would be expected on average.

Jones (2018, Chapter 4) also conducted a small field study where DGA and BAPMA forms of dicamba were directly applied to a sensitive soybean variety. Applications were made on the same day and growth stage as the large field drift experiment presented in Chapter 4. Row spacing, irrigation, and weed control measures were also the same as in the large field experiment. Ten dicamba doses (56, 17.5, 5.6, 1.75, 0.56, 0.175, 0.056, 0.0175, 0.0056, and 0.00175 g ae/ha) for each formulation were applied to the center two rows of each four-row plot using a CO_2-pressurized backpack sprayer with a 1.5-m spray boom equipped with four AIXR110015 nozzles (TeeJet Technologies) with an output of 143 L/ha (15.3 gal/A) at 275 kPa (40 psi). Treatments were arranged in a randomized complete block design and included four replications. Injury ratings were taken 7, 14, and 21 DAA. Data were subjected to a two-way ANOVA to test for effects of rate, formulation, and the interaction between rate and formulation as related to injury at 21 DAA. Injury data were also subjected to regression analysis to determine goodness of fit. For each year, a model describing the natural logarithm of the dose (g ae/ha) as a function of injury (%) at 21 DAA was produced. Plant heights were also collected 21 DAA and subjected non-linear regression analysis. Various exponential models were tested and goodness of fit was decided. EPA reviewed the regressions and empirical measurements reported by Jones and concluded that injury to height ratios would fall within the range of values presented in **Table A.1** for other studies (~1-3). However, there was low confidence in the estimates at the 5% effect level due to extrapolation below the lowest tested dose and poor fit of the model at these levels

EPA also included the review of another field study (Knezevic et al. 2018) which evaluated the impact on tomato and grape plants after direct spraying of dicamba (three different formulations) in the field. Tomatoes and grapes were treated at five different rates (0.56, 1.12, 5.6, 11.2, 56 g ae/ha) of three dicamba-based products (Clarity, Engenia, and XtendiMax). Each species of plant was treated at two different stages of growth (based on tomato height and grape vine length). Separate experiments were conducted over two years. Plants were evaluated for severity of % injury (7, 14, 21, and 28 days after treatment (DAT)), tomato height/grape vine length (14 and 28 DAT), and plant biomass (14 and 28 DAT). Analysis of the data calculated the Effective Dose (ED) at 10, 20 and 50 % effect for each measured variable.

Length (i.e., tomato shoot height and grape vine length), was analyzed by the study author in terms of individual dicamba products. However, biomass estimates were combined across products in the study report. EPA estimated 5% and 25% Inhibition Concentrations (IC_{05} and IC_{25}) values to compare with results from registrant-submitted toxicity studies on dicamba. Regressions were carried out in Excel using linear, exponential, and power regression of the reported ED_x values for length and biomass. Linear regressions (intercept set to zero) were generally judged poor fits and were therefore excluded as reviewer calculated IC_{05} values typically exceeded the reported ED_{10} values. The power and logistic regressions each fit the data well ($r^2 > 0.98$), and the power regression results were selected based on their r-squared estimates.

Based on comparisons of the tomato height DGA and BAPMA IC_{25}s, Knezevic et al. (2018) results (IC25s = 1.579 and 2.527 g ae/ha for DGA and BAPMA, respectively) are more sensitive than the height endpoints reported for both DGA (3.25 g ae/ha) and BAPMA (2.77 g ae/ha) in greenhouse studies using tomato (MRIDs 47815102 and 48718015 respectively). The corresponding tomato IC_{05} height estimates for Knezevic et al. (2018; DGA IC_{05} = 0.086 g ae/ha; BAPMA IC_{05} = 0.55 g ae/ha) were also more sensitive than the greenhouse tomato IC_{05} (0.65 g ae/ha) for DGA and is slightly higher than the BAPMA estimate (IC_{05} = 0.386 g ae/ha).

Because the biomass ICx estimates were based on the combined results from multiple experiments and are not specific to DGA or BAPMA, it is not possible to directly compare against the DGA and BAPMA products individually. However, the reviewer's IC_{25} estimate (1.836 g ae/ha) suggest that the tomato biomass IC_{25} for DGA in the registrant submitted greenhouse study (0.59 g ae/ha) was more sensitive (MRID 47815102). The registrant submitted BAPMA IC25 for biomass was 4.52 g ae/ha. Therefore, the combination of DGA and BAPMA data in Knezevic et al. (2018) likely represents a similar distribution of effects, adding to uncertainty in the relative sensitivity in comparison to the DGA greenhouse result.

The results for grape indicate that based on the observed dicamba effects on vine length and biomass, the tomato was more sensitive of the two crops.

In comparison to the established regulatory endpoints for DGA and BAPMA from the registrant submitted greenhouse studies (MRID 47815102 and 48718015), the Knezevic IC_{25} estimates are less sensitive in terms of the IC_{25}. However, the tomato IC_{05} estimates (DGA IC_{05} = 0.086 g ae/ha; BAPMA IC_{05} = 0.55 g ae/ha) are below the regulatory endpoint selected from soybean for DGA (0.293 g ae/ha) and slightly higher than the BAPMA endpoint (0.336 g ae/ha). In keeping with Agency policy, the selection of the most sensitive endpoint for is first determined based upon the IC_{25} (USEPA, 2005), where there is greater confidence in the regression estimate since the estimates are bounded by the data; therefore, the established regulatory endpoint is unchanged.

The following table provides a summary of available studies containing simultaneous scoring of visual signs of injury and measures of height or yield. These studies were all effects studies conducted as dose response studies where measurements of VSI, height and yield were made at a number of dicamba exposure levels (g/ha). Some studies (*e.g.,* Jones 2018, Silva et al. 2018, and Knezevic et al. 2018) measured each variable and established separate regressions of effects without relating VSI to height or yield. In other cases (*e.g.*, Foster and Griffin 2018, Growe 2017 and Robinson et al. 2013) the authors set out from the initiation of the study to establish relationships between VSI and other effects endpoints. In still others, the authors (Kniss 2018) performed a metadata analysis of other research for the express purpose of relating VSI levels to other effects endpoints. Lastly, registrant submitted laboratory vegetative vigor studies (MRIDs 47815102 and 48718014) contain sufficient information for EPA to directly compare VSI effects recorded in the observations with the effects endpoints commonly measured for growth (*e.g.,* plant height).

With the exception of the Kniss (2018) metadata analysis where the ratio of VSI to 5% yield was established in the publication, EPA evaluated each study with a common approach. First the Agency established the dicamba dose associated with either a 5% height or 5% yield reduction (effects determination endpoints) from the study's available dose response data. EPA then consulted the dose response relationship of VSI from the same study and growth stage and determined the level of VSI that corresponds with the dose shown to cause the 5% reduction in height or yield. EPA then established a ratio of % visual injury to % reduction in height or yield by dividing the VSI% by the 5% level of height or yield. The reader will note that, in accordance to the biological basis for utilizing data appropriate to the life stage of the plant (see sections above) EPA limited these comparisons to height or yield as appropriate for the V or R stage growth phases, respectively. **Table A.1** provides the ratios for each study while the within data range deciles are shown in **Table A.2**.

Table A.1. Relationship of Visual Signs of Injury to Plant Height or Plant Yield Effects from Peer Reviewed Publicly Available Literature

Study ID ***Product*[1]**	**Number of Data Points**	**Growth Stage**	**Ratio of % visual injury to % reduction in height**	**Ratio of % visual injury to % reduction in yield**	**Estimation Method**
Vegetative Growth Stage					
Silva et al. (2018) *TEP not reported*	1	Soybean (V5)	6.7	Not reliable at this growth stage	Regression-based value at 5% reduction in height
Foster and Griffin (2018) *Clarity*	1	Soybean (V3/V4)	9.4	Not reliable at this growth stage	Regression-based value at 5% reduction in height
Growe (2017) *Clarity*	3	Soybean (V4)	3.2 4.3 1.0	Not reliable at this growth stage	Regression-based value at 5% reduction in height

Study ID *Product*[1]	Number of Data Points	Growth Stage	Ratio of % visual injury to % reduction in height	Ratio of % visual injury to % reduction in yield	Estimation Method
Knezevic et al. (2018) *Clarity*[1], *Engenia, XtendiMax*	2	Tomato	0.7 (Xtendimax) 1.5 (Engenia)	Not reliable at this growth stage	Regression-based value at 5% reduction in height
Knezevic et al. (2018) *Clarity*[1], *Engenia, XtendiMax*	2	Grape	2.3 (Engenia) 5.8 (Xtendimax)	Not reliable at this growth stage	Regression-based value at 5% reduction in height
MRID 47815102-Laboratory Test (*Clarity*)	1	Soybean (V3/V4)	2.1	Not reliable at this growth stage	Regression-based value at 5% reduction in height
MRID 48718014-Laboratory Test (*Engenia*)	1	Soybean (V3/V4)	2.5	Not Reliable at this growth stage	Regression-based value at 5% reduction in height
Reproductive Growth Stage					
Kniss (2018) *TEP not reported*	4	Soybean (R1/R2)	Not reliable at this growth stage	3.6 2.2 2 2.4	Regression-based value at 5% reduction in yield
Silva et al. (2018) *TEP not reported*	1	Soybean (R2)	Not reliable at this growth stage	2.2	Regression-based value at 5% reduction in yield
Foster and Griffin (2018) *Clarity*		Soybean (R1/R2)	Not reliable at this growth stage	6.7	Regression-based value at 5% reduction in yield

Study ID *Product*[1]	Number of Data Points	Growth Stage	Ratio of % visual injury to % reduction in height	Ratio of % visual injury to % reduction in yield	Estimation Method
Growe (2017) *Clarity*	1	Soybean (R2)	Not reliable at this growth stage	1.5	Regression-based value at 5% reduction in yield
Robinson et al. (2013) *Clarity*	1	Soybean (R2)	Not reliable at this growth stage	4	Regression-based value at 5% reduction in yield
Jones (2018) Chapter 1 trials *Clarity*	18	Soybean (R1)	Not reliable at this growth stage	7.18	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	7.1	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	6.45	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	8.36	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	7.16	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	2.13	Regression-based value at 5% reduction in yield
		Soybean (R2)	Not reliable at this growth stage	0.58	Value discarded because yield for entire trial was reduced

Study ID *Product*[1]	Number of Data Points	Growth Stage	Ratio of % visual injury to % reduction in height	Ratio of % visual injury to % reduction in yield	Estimation Method
			Not reliable at this growth stage	5.44	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	Not calculable	No yield loss reported
			Not reliable at this growth stage	8.9	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	Not calculable	No visible injury reported
			Not reliable at this growth stage	Not calculable	No yield loss reported
		Soybean (R3)	Not reliable at this growth stage	4.83	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	3.09	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	Not calculable	No yield loss reported

Study ID *Product*[1]	Number of Data Points	Growth Stage	Ratio of % visual injury to % reduction in height	Ratio of % visual injury to % reduction in yield	Estimation Method
			Not reliable at this growth stage	1.95	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	Not calculable	No yield loss reported
		Soybean (R4)	Not reliable at this growth stage	1.84	Regression-based value at 5% reduction in yield
			Not reliable at this growth stage	Not calculable	No yield loss nor injury reported
		Soybean (R5)	Not reliable at this growth stage	Not calculable	No yield loss reported

[1] As the registered products for dicamba use on dicamba-tolerant crops are Xtendimax and Engenia formulations, where studies used multiple TEP, including the registered products, EPA focused the analysis on the relevant registered products. However, if only unregistered formulations for over the top use (*e.g.* Clarity) data were available, then EPA used this data.

Table A.2. Within Soybean Range Ranked Percentiles for VSI:Effects Ratios

Percentile Range	Vegetative Growth Stage VSI:Height Ratios	Reproductive Growth Stage VSI:Yield Ratios
5%	1.33	1.5
10%	1.66	1.84
15%	1.99	1.95
20%	2.18	2
25%	2.3	2.13
30%	2.42	2.2
35%	2.57	2.2
40%	2.78	2.4
45%	2.99	3.09
50%	3.2	3.6
55%	3.53	4
60%	3.86	4.83
65%	4.19	5.44
70%	4.78	6.45
75%	5.5	6.7
80%	6.22	7.1
85%	6.97	7.16
90%	7.78	7.18
95%	8.59	8.36

A.4 VSI:Effects Ratio Uncertainties, Limitations, and Conclusions

There is considerable overlap in the ranges of VSI:Effect ratio for both V-stage plant height and R-stage plant yield measures suggesting that the selection of a ratio for each relationship of VSI with an appropriate effects determination measurement endpoint can be selected in common.

Potential contributing factors for the range in observations across the studies within each VSI:Effect ratio calculation may be the effects of factors that affect overall growth and maturation of soybeans. These may include soybean cultivar, meteorological conditions (*e.g.*, temperature and rainfall) and soil conditions (*e.g.*, soil fertility and moisture holding). The effects of these environmental variables among the studies cited in **Table A.1** is not quantitatively known. The available data show that the range for field-derived studies encompasses the ratios derived for the two laboratory studies (MRID 47815102 and 48718014), where environmental conditions were selected to optimize growth.

One uncertainty with using this dataset is that none of these studies, with the possible exceptions of Silva *et al* (2018) and the registrant-submitted study using BAPMA salt (MRID 48718014) used the currently registered dicamba formulations for DT-crops (Xtendimax or Engenia). It is unknown the exact impact that the formulation used might have on the nature and extent of toxicity or on the ratio of VSI to apical endpoint. However, it is notable that in the registrant-submitted laboratory studies with DGA (Clarity™) and BAPMA salts (MRIDs 47815102 and 48718014, respectively, both conducted at the same laboratory, but in different years), the formulation used appeared to have near negligible impacts on the toxic effects observed. For example, an application of 0.00026 lb ae/A Clarity™ resulted in a 9.2% inhibition of soybean plant height, relative to controls, while an equivalent rate of BAPMA salt (0.0003 lb ae/A) had a 4.8% inhibition of soybean plant height, relative to controls. Similarly, the ratio of %VSI to %plant height effects was 2.1 and 2.5, respectively for the DGA and BAPMA salt formulations. This suggests that the impact of formulation on toxic effects may be a limited source of variability compared to other factors (*e.g.* study site, researcher, differing study protocols, etc.)

The limited data available in **Table A.1** for tomatoes and grapes suggest that other plant species have the potential to fall within the bounds of VSI:effects relationships. But again, just as growing conditions and cultivars yield varying relationships between VSI and height or yield effects, it is reasonable to also expect these confounding effects in other non-target plants. The data for tomatoes and grapes was therefore not included in the calculation of equivalent percentile ranks presented for soybean in **Table A.2.**

In summary, the consideration of the data in **Table A.1** for the evaluation of VSI observations in other field studies of primary and secondary drift of dicamba should:

1. Assign VSI ratios appropriate for the growth stage of the plant
2. Consider the potential uncertainty surrounding the subjective nature of VSI scoring; inconsistencies are likely, in the absence of standardized VSI scoring across studies.
3. Recognize that the growth stages of listed plants in the wild will likely not always coincide with that of soybeans or other agricultural crops
4. The ratio between VSI and height or yield for wild plants may occur across the distribution of values identified to date, and may indeed go higher or lower.
5. The environmental conditions affecting plant growth for the soybeans studies in the data in **Table A.1** are likely also important drivers for other plant species
6. Formulation is not expected to be a confounding factor when establishing plant responses to known dicamba doses.

A.5 Considerations of the VSI Approach

The VSI approach has the advantage (related to the direct effects measurement approach) of having a larger pool of data that encompasses more field trials, under more variable environmental conditions and performed in more geographic locations. Over a dozen studies measured visual signs of injury for both V and R stage plants. Forty-five separate transects were measured in all (21 for Engenia and 24 for Xtendimax). Where height measures were simultaneously measured these were included in the results. All levels of VSI were related to thresholds of height or yield effects using the distribution analysis of VSI relationships on over multiple published effects studies with simultaneous measures at appropriate growth stages.

However, with these advantages comes the uncertainties associated with the available data used to establish VSI:Effects ratios. Notable is the uncertainty associated with the subjective nature of the VSI scoring procedure compounded by the lack of performance criteria to evaluate the consistency of such scoring efforts across the field studies. The likely net effect of this uncertainty is an increase in the breadth of reported ranges, because of the variability in scoring the VSI portion of the ratio. For a discussion on the uncertainties associated with the field studies that report VSI measures used in approach, see Section 4.6.

In interpreting this VSI threshold for distance from the field to effects, EPA considered the predicted distance to a 20% level of VSI as the surrogate for a 5% effect on height or yield for many field-study transects. In cases where a field study measured effects to plant height directly (there were no yield measures), the distances to the 5% height were used in place of the distance predicted for a 20% level of VSI.

A distribution-based analysis was performed for all of the predicted distances to a 20% level of VSI or a 5% level of height, when measured in the study. This was performed for all available transects combined or the transects associated with field studies for each formulation alone (Engenia or Xtendimax).

EPA's routine exposure estimation methods for assessing the potential for effects to listed species involves the use of a reasonable upper bound estimate for establishing exposure levels. This approach is used for exposure estimation in 1) aquatic phase organisms using the PWC model and 2) refined spray drift exposure for terrestrial and aquatic organisms using the AgDRIFT model. In addition, previous effects determinations for dicamba used a reasonable upper bound estimate for volatile drift exposure for using the PERFUM model. For the current effects determination, considering both spray drift and volatile drift exposure to terrestrial plants in the off-site areas, EPA has explored the establishment of a reasonable upper bound estimate for the distance from the field using a distributional approach combining the effects to distance data for all the available field studies (see **Appendix B**).
The Agency created probability distribution for the following variable and data sets:

1. Distance from the treatment field edge to a point related to 10% VSI for all field studies reporting visual signs of damage (10 % VSI selected to represent 5% effects on height or yield)
2. Distance from the treatment field edge to a point related to 10% VSI for Engenia field studies reporting visual signs of damage.
3. Distance from the treatment field edge to a point related to 10% VSI for Xtendimax field studies reporting visual signs of damage.
4. Distance from the treatment field edge to a point related to 20% VSI for all field studies reporting visual signs of damage. (20 % VSI selected to estimate 5% effects on height or yield)
5. Distance from the treatment field edge to a point related to 20% VSI for Engenia field studies reporting visual signs of damage.

6. Distance from the treatment field edge to a point related to 20% VSI for Xtendimax field studies reporting visual signs of damage.
7. Distance from the treatment field edge to a point related to direct estimate of 5% height for all field studies reporting height in V stage plants.
8. Distance from the treatment field edge to a point related to direct estimate of 5% height for Engenia field studies reporting height in V stage plants.
9. Distance from the treatment field edge to a point related to direct estimate of 5% height for Xtendimax field studies reporting height in V stage plants.

When establishing the VSI distributions, and to maintain the use of direct measures whenever practical and robust, if a study reported both VSI and plant height data, the Agency made a decision to rely on the distance to 5% height reduction because it was a direct measure of the apical endpoint used in risk assessment and did not include the subjective nature inherent in VSI scoring. EPA used Crystal Ball add-in software to Excel to fit distribution functions to the data sets. Crystal Ball enables the user to fit various probability distribution functions to a data set and then sample those distributions thousands of times using Monte Carlo probabilistic algorithms to test the extent to which the selected distributions tend to over or underestimate any segment of the distribution of the variable. Because EPA is interested in reasonable upper bound estimates for the purposes of the effects determination distance to effects analysis, the Agency selected a distribution to fit to the data that would be a more accurate representation of the dispersion of data at the upper limits of the distribution. For the VSI-based calculations, where the number of studies allowed Crystal Ball to directly fit the distribution, EPA fit the data to exponential functions. In the case of the height measurement distributions, the number of available data points was too limited for Crystal Ball software to directly fit a distribution. In those cases, EPA first looked at the summary statistics of the data sets to confirm the comparison of mean and median estimates were sufficiently shifted to suggest a non-normal distribution, and then fit a log normal distribution to the data sets using the mean and standard deviation of the data set as the fitment parameters.

EPA than tested the predictive quality of the distributions by sampling the distributions using Crystal Ball's Monte Carlo random sampling algorithms (random seed, Monte Carlo sampling). EPA then compared the upper quantiles of the data, the fit distribution, and the distribution of randomly sampled values to see if the results produced inconsistent upper quantile values (70%, 80% and 90%). The fitment was considered reasonable if the comparison of the data, the fit distribution and the distribution of randomly sampled values were consistent.

Appendix C provides the Crystal Ball output for each distribution. Good agreement between data, fit distribution, and resampled distribution was found in all cases up through the 90th percentile. **Table A.3** below summarizes the findings of the VSI-based and height-based evaluations of distance to effects. As was discussed in earlier sections, the uncertainties associated with VSI scoring, would suggest a reasonable selection from the distribution of distances to VSI effects from the upper bound of the central portion of the available distributions (i.e., ~70-75th %-ile). This avoids potentially unrealistic predictions towards the tails of the distribution which are further confounded by the uncertainties. The 70-75%-tile yields a predicted distance to a reasonably expected effects threshold of 20% VSI (or 5% height when measured) of 17-20 meters. Furthermore, it is also reasonable to expect that the distances measured to a 20% VSI threshold, based on the critical relationships established in Table A.3 will also be protective of the reproductive endpoint because there is a high degree of similarity of VSI ratios for both height and yield.

Table A.3. Comparison of Distances to Effect for Dicamba Products

Percentile	All products (n=47)	Engenia (n=22)	Xtendimax (n=25)
Distance to 20% VSI (m)			
95%	43.24	44.18	42.77
90%	34.08	34.12	33.02
85%	27.88	27.99	27.44
80%	23.77	23.73	23.30
75%	20.21	20.43	20.15
70%	17.67	17.62	17.64
65%	15.51	15.36	15.38
60%	13.46	13.45	13.36
55%	11.77	11.77	11.58
50%	10.20	10.24	10.11
45%	8.81	8.84	8.58
40%	7.54	7.56	7.32
35%	6.35	6.38	6.17
30%	5.24	5.24	5.09
25%	4.21	4.12	4.02
20%	3.23	3.20	3.06
15%	2.33	2.36	2.21
10%	1.48	1.52	1.43
5%	0.70	0.74	0.69
Distance to 5% Plant Height Reduction (m)			
Percentile	All products (n=15)	Engenia (n=4)	Xtendimax (n=11)
95%	17.45	47.89	7.47
90%	15.06	39.60	6.71
85%	13.62	34.85	6.21
80%	12.57	31.50	5.86
75%	11.76	29.10	5.56
70%	11.11	26.99	5.32
65%	10.52	25.24	5.09
60%	9.99	23.61	4.88
55%	9.53	22.15	4.70
50%	9.09	20.78	4.53
45%	8.65	19.48	4.37
40%	8.22	18.29	4.20

35%	7.82	17.15	4.03
30%	7.43	16.01	3.86
25%	7.05	14.88	3.68
20%	6.60	13.72	3.48
15%	6.11	12.50	3.26
10%	5.53	11.09	3.02
5%	4.79	9.29	2.71
0%	2.10	3.21	1.39

Appendix B. Field Studies Data

B1. Protocol for Academic Large-Scale Off-Target Movement Assessment of Dicamba Methods

A series of trials were designed to evaluate off-target movement (OTM) via physical drift and volatility when applied to large areas (10 – 40 acres). Applications were made under conditions consistent with the current XtendiMax label. Tank mixtures of XtendiMax + PowerMax + Intact were applied in an application volume of 15 GPA from a commercial sized sprayer traveling no more than 15 MPH. The treatments were applied with TTI 11004 spray nozzles with a sprayer traveling approximately 10 MPH. Applications were made between sunrise and sunset while winds speeds were between 3 and 10 MPH. Off-target movement was assessed via air samplers, horizontal mylar sample collectors, and a bio-indicator crop of non-Xtend soybean. These large-scale trials were conducted by the University of Arkansas, University of Wisconsin-Madison, Purdue University, Michigan State University, and the University of Nebraska

Treated areas were planted with Roundup Xtend soybeans while the surrounding area was planted with a non-Xtend soybean of a similar maturity group. Applications are designed to target the largest soybean possible before reaching a flowering stage. In the south this would approximate a soybean application at V5-V6, where plants are approximately 10-12 inches tall. The treated areas were surrounded by non-Xtend soybean, such that samples could be taken for a minimum of 300 feet.

Figure B.1 provides a schematic of the sampling regime for the large-scale studies. Horizontal sample collectors were collected and placed in uniquely labeled containers following application of the test substances and then sent to the University of Nebraska for analysis. Downwind sample stations were located at various distances (4, 8, 16, 30.5, 45, 60, 75, 90, 105, 120 m) downwind of the application, determined by the available site-specific wind direction at the time of the study. The field line was defined as the edge of the spray from the furthest downwind nozzle on the boom. Three such lines of sample collectors were used for each treatment, spaced a minimum of 15 m apart, as appropriate for the test site and local landscape, with the center line located from the midpoint of the spray swath length, as appropriate for the site being used. A Mylar collector was placed at each location for collecting samples of the test substance. Each sample station used a horizontal structure to mount the collectors at crop height. Downwind sample collectors were collected 30 minutes after the spray application concluded. Additionally, three upwind sample collectors were collected, each located on the depositional sample transects at 30 m from the upwind edge of the application area. This is consistent with the trials that were conducted by the Spray Drift Task Force in the 1990s.

To assess volatility, PUF samples were collected and placed in uniquely labeled containers, to be analyzed by the Mississippi Department of Agriculture State Chemical Laboratory. Two pre-application air samples were collected using air sampling equipment placed near the in-field air monitoring location (center of plot) of the test plot. The samples were collected 24 – 48 hours prior to the start of the application. The pre-application air monitoring event lasted approximately 6 hours. These samples were used to determine the level of background dicamba within the application area. In-field air samplers were placed in the approximate center of the treated area and in each of 8 directions from the treated area. Samplers were turned on 30 minutes after completion of the application to the entire plot. The in-field air profile monitoring station in the plot consisted of air samplers mounted on a sampling mast located at the approximate center of the plot. The samplers located outside the treated area were located at a distance of 15 meters from the treated area. All air samplers will be located on the sample mast at approximately 0.33 m above the crop canopy. After application, PUFs were collected from the sample mast. The PUFs were collected approximately 6, 12, 24, 36, 48, 60, and 72 hours following completion of the application to the entire plot.

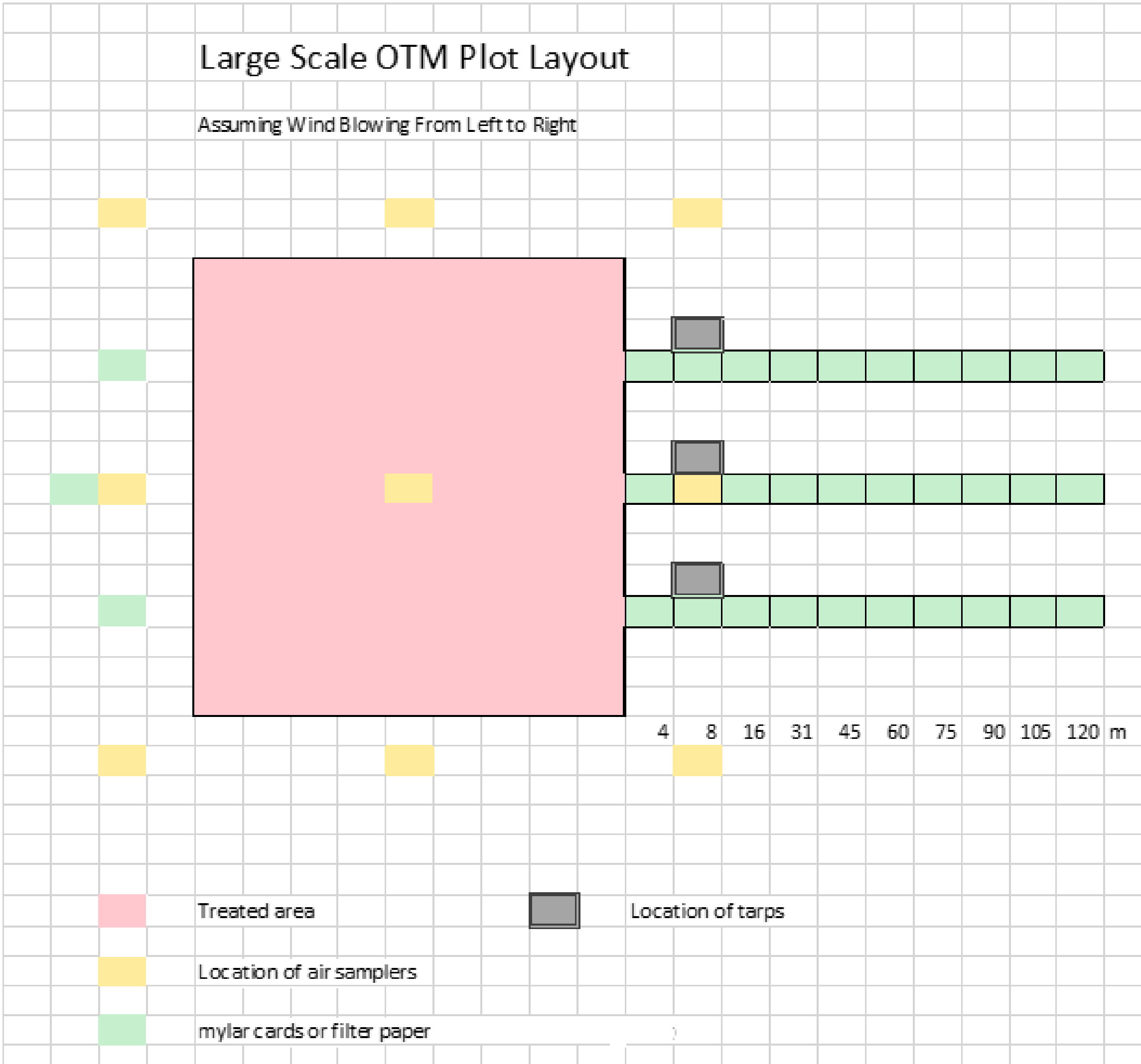


Figure B.1. Large Area Applications, Field Layout

Spray drift impacts on non-tolerant soybean were assessed by comparing plant heights and visual plant response along transects perpendicular to the edges of to a distance of 100 m. Plant effects from volatility were assessed by covering a portion of the soybean crop during the application period to prevent exposure to spray drift. The cover was removed post-application. Plant heights were measured approximately 14 and 21 days post-application on ten plants at each distance along each transect. Plants were selected non-systematically and without measuring the same plant more than once. Height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud. Where multiple shoots were present, measurements along the main shoot were taken. Measurements were made to the nearest one-half cm using a standard ruler. Control (untreated) plants were measured just prior to the application at each site as a measure of inherent variability in the plant sizes across the field. Control measurements prior to application were taken non-systematically across the field in areas where spray treatments were to be made as well as upwind and downwind areas. In addition, upwind plant height measurements were taken on the day assessments were made. These measurements were taken at least 50 to 100 m upwind of the “upwind edge” of each sprayed area and in areas where visual dicamba symptomology was not expected.

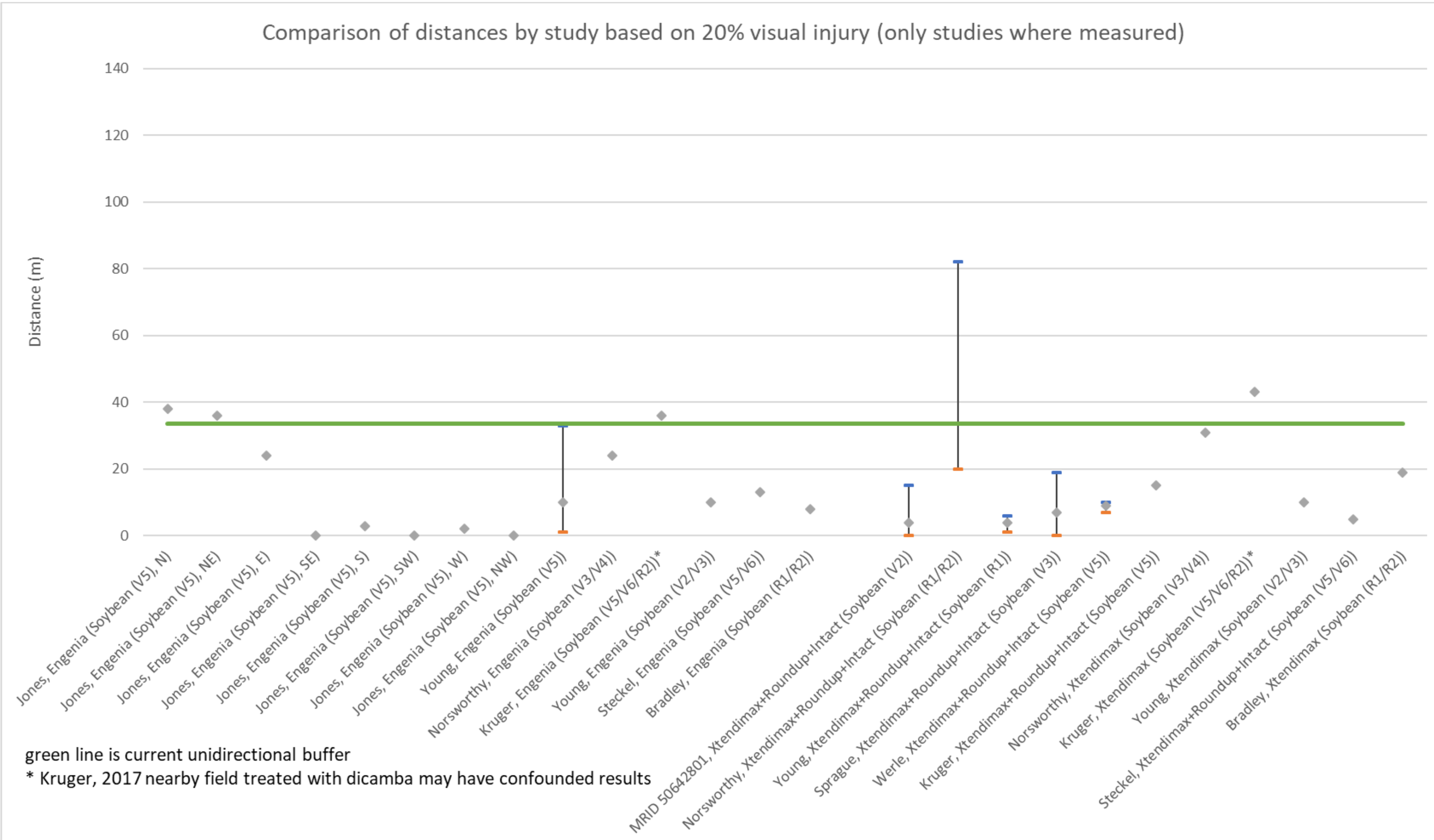
Visual plant response was assessed on a scale of 0 to 100 with 0 representing no visible plant response and 100 representing complete plant death. This plant response rating scale was conducted consistent with visual plant response ratings described in Frans (Frans, 1977), Behrens and Lueschen (Behrens, 1979), and Sciumbato et al. (Sciumbato et al., 2004). For selected plots and timings, photographs were made to document the visual plant response symptoms, and severity at specified distances.

Appendix B2. Table of Results for All Field Data Considered

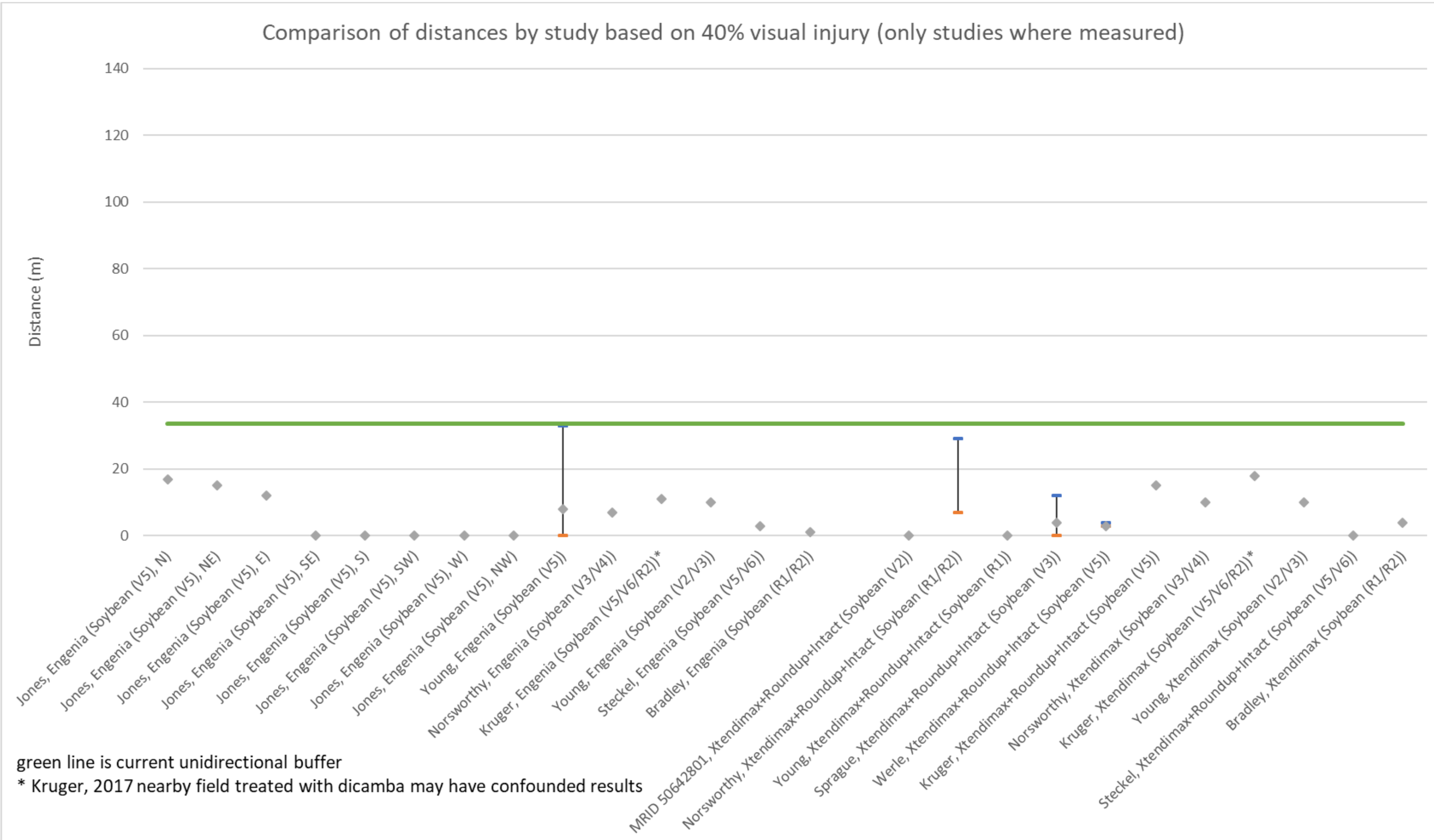
Study ID	Location	Acres treated	Date of Application	Field condition	Average Distance (m) to 10% visual injury (min – max)	Average Distance (m) to 20% visual injury (min – max)	Average Distance (m) to 40% visual injury (min – max)	Average Distance (m) to 5% reduction in height (min – max)	Average Distance (m) to 5% reduction in yield (min – max)
Field Studies									
Product = Engenia									
Jones	AR		7/6/16	Soybean (V5), N	**59**	**38**	**17**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), NE	**57**	**36**	**15**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), E	**37**	**24**	**12**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), SE	**21**	**0**	**0**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), S	**9**	**3**	**0**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), SW	**0**	**0**	**0**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), W	**6**	**2**	**0**	Not assessed	Not assessed
Jones	AR		7/6/16	Soybean (V5), NW	**11**	**0**	**0**	Not assessed	Not assessed
Young[1]	IN	0.9	8/3/18	Soybean (V5)	**12 (0 – 34)**	**10 (1 – 33)**	**8 (0 – 33)**	Not assessed	Not assessed
Norsworthy	AR	3.5	7/20/17	Soybean (V3/V4)	**40**	**24**	**7**	**24 (1 – 55)**	Not assessed
Kruger[2]	NE	0.17	7/6/17	Soybean (V5/V6/R2)	**67**	**36**	**11**	Not assessed	Not assessed
Young	IN	3.0	8/27/17	Soybean (V2/V3)	**<10**	**<10**	**<10**	Not assessed	Not assessed
Steckel	TN	2.0	7/27/17	Soybean (V5/V6)	**27**	**13**	**3**	Not assessed	Not assessed
Bradley	MO	2.6	7/20/17	Soybean (R1/R2)	**28**	**8**	**1**	Not assessed	Not assessed
Product = Xtendimax									
49888501	GA	3.4	5/5/15	Bare	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
49888503	TX	9.6	6/8/15	Cotton	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
Norsworthy	AR	3.5	7/20/17	Soybean (V3/V4)	**52**	**31**	**10**	**< 3**	Not assessed
Kruger[2]	NE	0.17	7/6/17	Soybean (V5/V6/R2)	**69**	**43**	**18**	Not assessed	Not assessed
Young	IN	3.0	8/27/17	Soybean (V2/V3)	**<10**	**<10**	**<10**	Not assessed	Not assessed
Bradley	MO	2.6	7/20/17	Soybean (R1/R2)	**41**	**19**	**4**	Not assessed	Not assessed
Product = Xtendimax + Roundup									
49888601	GA	3.4	5/5/15	Bare	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
49888603	TX	9.6	6/8/15	Cotton	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
50578903	TX	4.6	10/4/16	Bare	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
50578903	TX	9.1	10/4/16	Cotton	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
50606801	Australia	37	12/15/17	Soybean (V4?)	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed
50642801	AZ	27	5/8/18	Soybean (V2)	**8 (0 – 25)**	**4 (0 – 15)**	**0**	Not reliable	Not assessed
Norsworthy[3]	AR	38.5	7/16/18	Soybean (R1/R2)	**34 - 136**	**20 – 82**	**7 - 29**	Not reliable	**Waiting on data**

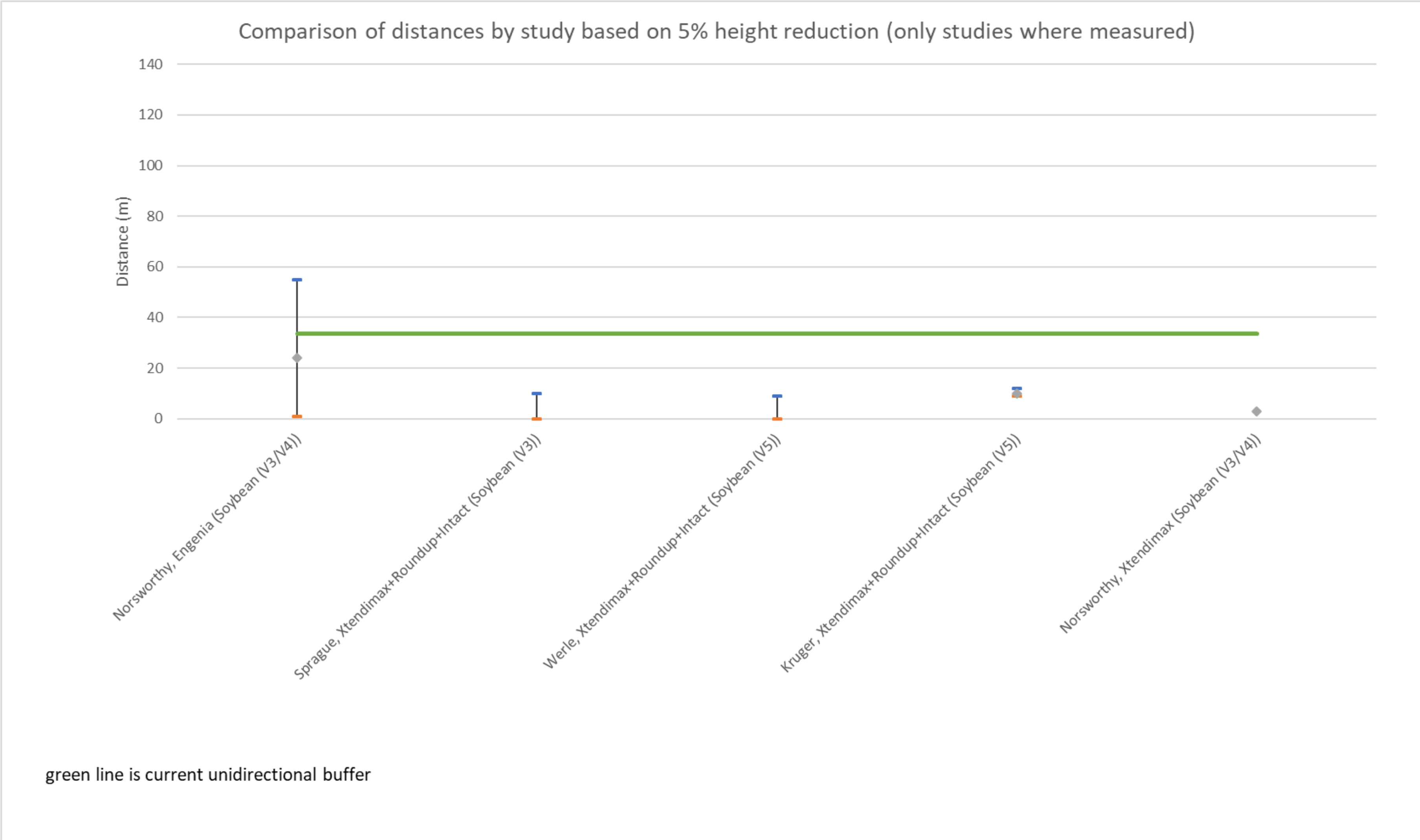
Study ID	Location	Acres treated	Date of Application	Field condition	Average Distance (m) to 10% visual injury (min – max)	Average Distance (m) to 20% visual injury (min – max)	Average Distance (m) to 40% visual injury (min – max)	Average Distance (m) to 5% reduction in height (min – max)	Average Distance (m) to 5% reduction in yield (min – max)
Werle[4]	WI	8	7/11/18	Soybean (V5)	**15 (12 – 17)**	**9 (7 – 10)**	**3 (3 – 4)**	**0 – 9**	Not assessed
Young[5]	IN	20	8/9/18	Soybean (R1)	**14 (6 - 20)**	**4 (1 – 6)**	**0**	Not reliable	Not assessed
Sprague[6]	MI	53	6/12/18	Soybean (V3)	**16 (2 – 25)**	**7 (0 – 19)**	**4 (0 – 12)**	**0 - 10**	Not assessed
Kruger	NE	30	7/10/18	Soybean (V5)	**>15**	**>15**	**>15**	**10 (9 – 12)**	Not assessed
Steckel	TN	2.0	7/27/17	Soybean (V5/V6)	**18**	**5**	**0**	Not assessed	Not assessed

1. Distance to 10% damage not provided in study. Values represent distance to < 10%, 10-30%, and > 30% along East side of field, side with largest values, at 28 days after treatment.
2. The Kruger, 2017 results may have been confounded by nearby application of dicamba during study.
3. According to protocol, TTI11004 nozzles were supposed to be used. UR11010 was used and is allowed on the label. Height data were collected, but because the growth stage was reproductive, the results were not considered reliable.
4. Transect that reported height damage showed no visual signs of injury, while transects that showed no plant height reductions showed visual injury.
5. In Young, 2018, drift transects were along the East and West directions, but a review of the meteorological data indicated winds were primarily out of South. Height data were collected, but because the growth stage was reproductive, the results were not considered reliable.
6. In Sprague, 2018, drift transects were along North and West directions, but a review of the meteorological data indicated winds were primarily out of Northeast and Southwest.



Comparison of distances by study based on 20% visual injury (only studies where measured)
Distance (m)
140
120
100
80
60
40
20
0
Jones, Engenia (Soybean (V5), N)
Jones, Engenia (Soybean (V5), NE)
Jones, Engenia (Soybean (V5), E)
Jones, Engenia (Soybean (V5), SE)
Jones, Engenia (Soybean (V5), S)
Jones, Engenia (Soybean (V5), SW)
Jones, Engenia (Soybean (V5), W)
Jones, Engenia (Soybean (V5), NW)
Young, Engenia (Soybean (V5))
Norsworthy, Engenia (Soybean (V3/V4))
Kruger, Engenia (Soybean (V5/V6/R2))*
Young, Engenia (Soybean (V2/V3))
Steckel, Engenia (Soybean (V5/V6))
Bradley, Engenia (Soybean (R1/R2))
MRID 50642801, Xtendimax+Roundup+Intact (Soybean (V2))
Norsworthy, Xtendimax+Roundup+Intact (Soybean (R1/R2))
Young, Xtendimax+Roundup+Intact (Soybean (R1))
Sprague, Xtendimax+Roundup+Intact (Soybean (V3))
Werle, Xtendimax+Roundup+Intact (Soybean (V5))
Kruger, Xtendimax+Roundup+Intact (Soybean (V5))
Norsworthy, Xtendimax (Soybean (V3/V4))
Kruger, Xtendimax (Soybean (V5/V6/R2))*
Young, Xtendimax (Soybean (V2/V3))
Steckel, Xtendimax+Roundup+Intact (Soybean (V5/V6))
Bradley, Xtendimax (Soybean (R1/R2))
green line is current unidirectional buffer
* Kruger, 2017 nearby field treated with dicamba may have confounded results


Comparison of distances by study based on 40% visual injury (only studies where measured)
Distance (m)
140
120
100
80
60
40
20
0
Jones, Engenia (Soybean (V5), N)
Jones, Engenia (Soybean (V5), NE)
Jones, Engenia (Soybean (V5), E)
Jones, Engenia (Soybean (V5), SE)
Jones, Engenia (Soybean (V5), S)
Jones, Engenia (Soybean (V5), SW)
Jones, Engenia (Soybean (V5), W)
Jones, Engenia (Soybean (V5), NW)
Young, Engenia (Soybean (V5))
Norsworthy, Engenia (Soybean (V3/V4))
Kruger, Engenia (Soybean (V5/V6/R2))*
Young, Engenia (Soybean (V2/V3))
Steckel, Engenia (Soybean (V5/V6))
Bradley, Engenia (Soybean (R1/R2))
MRID 50642801, Xtendimax+Roundup+Intact (Soybean (V2))
Norsworthy, Xtendimax+Roundup+Intact (Soybean (R1/R2))
Young, Xtendimax+Roundup+Intact (Soybean (R1))
Sprague, Xtendimax+Roundup+Intact (Soybean (V3))
Werle, Xtendimax+Roundup+Intact (Soybean (V5))
Kruger, Xtendimax+Roundup+Intact (Soybean (V5))
Norsworthy, Xtendimax (Soybean (V3/V4))
Kruger, Xtendimax (Soybean (V5/V6/R2))*
Young, Xtendimax (Soybean (V2/V3))
Steckel, Xtendimax+Roundup+Intact (Soybean (V5/V6))
Bradley, Xtendimax (Soybean (R1/R2))
green line is current unidirectional buffer
* Kruger, 2017 nearby field treated with dicamba may have confounded results

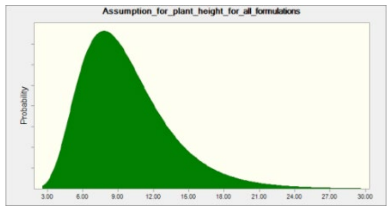


There is no figure for yield as none of the studies provided measured yield values.

Appendix C. Crystal Ball Outputs

Worksheet. Report percentiles provided from input fit distribution

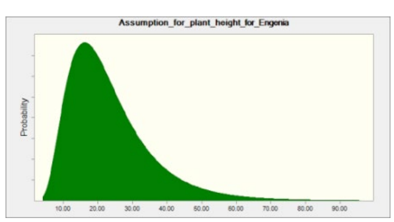
Assumption: Assumption_for_plant_height_for_all_formulations **Cell: B18**



Assumption: Assumption_for_plant_height_for_all_formulations (cont'd) **Cell: B18**

Percentiles:	Assumption values	Distribution
0%	2.10	0.00
5%	4.79	4.81
10%	5.53	5.53
15%	6.11	6.07
20%	6.60	6.54
25%	7.05	6.98
30%	7.43	7.39
35%	7.82	7.80
40%	8.22	8.20
45%	8.65	8.62
50%	9.09	9.04
55%	9.53	9.49
60%	9.99	9.97
65%	10.52	10.48
70%	11.11	11.06
75%	11.76	11.71
80%	12.57	12.49
85%	13.62	13.46
90%	15.06	14.79
95%	17.45	17.00
100%	37.30	Infinity

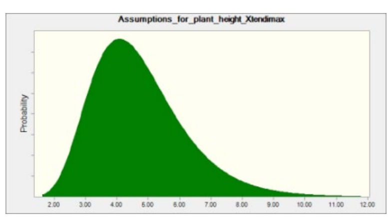
Assumption: Assumption_for_plant_height_for_Engenia **Cell: B20**



Assumption: Assumption_for_plant_height_for_Engenia (cont'd) **Cell: B20**

Percentiles:	Assumption values	Distribution
0%	3.21	0.00
5%	9.29	9.12
10%	11.09	10.94
15%	12.50	12.36
20%	13.72	13.63
25%	14.88	14.81
30%	16.01	15.97
35%	17.15	17.11
40%	18.29	18.28
45%	19.48	19.48
50%	20.78	20.75
55%	22.15	22.09
60%	23.61	23.54
65%	25.24	25.15
70%	26.99	26.96
75%	29.10	29.05
80%	31.50	31.58
85%	34.85	34.81
90%	39.60	39.34
95%	47.89	47.17
100%	137.75	Infinity

Assumption: Assumptions_for_plant_height_Xtendimax **Cell: B22**

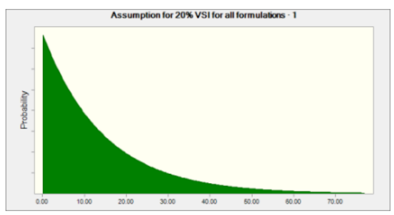


Assumption: Assumptions_for_plant_height_Xtendimax (cont'd) **Cell: B22**

Percentiles:	Assumption values	Distribution
0%	1.39	0.00
5%	2.71	2.70
10%	3.02	3.02
15%	3.26	3.26
20%	3.48	3.47

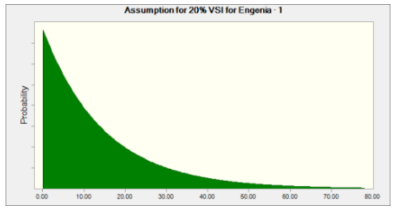
25%	3.68	3.65
30%	3.86	3.83
35%	4.03	3.99
40%	4.20	4.16
45%	4.37	4.33
50%	4.53	4.50
55%	4.70	4.68
60%	4.88	4.87
65%	5.09	5.08
70%	5.32	5.30
75%	5.56	5.56
80%	5.86	5.85
85%	6.21	6.22
90%	6.71	6.71
95%	7.47	7.52
100%	13.57	Infinity

Assumption: Assumption for 20% VSI for all formulations · 1 **Cell: B12**



Percentiles:	Assumption values	Distribution
0%	0.00	0.00
5%	0.74	0.74
10%	1.53	1.53
15%	2.32	2.36
20%	3.15	3.24
25%	4.12	4.18
30%	4.99	5.18
35%	6.10	6.26
40%	7.26	7.42
45%	8.47	8.68
50%	9.91	10.07
55%	11.46	11.60
60%	13.09	13.31
65%	14.92	15.24
70%	17.11	17.48
75%	19.80	20.13
80%	22.99	23.37
85%	26.97	27.55
90%	33.03	33.44
95%	43.51	43.50
100%	181.75	Infinity

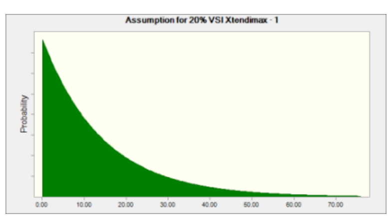
Assumption: Assumption for 20% VSI for Engenia · 1 **Cell: B14**



Assumption: Assumption for 20% VSI for Engenia · 1 (cont'd) **Cell: B14**

Percentiles:	Assumption values	Distribution
0%	0.00	0.00
5%	0.83	0.76
10%	1.66	1.55
15%	2.47	2.39
20%	3.27	3.29
25%	4.31	4.24
30%	5.37	5.25
35%	6.49	6.35
40%	7.62	7.52
45%	8.81	8.81
50%	10.21	10.21
55%	11.77	11.76
60%	13.54	13.50
65%	15.43	15.46
70%	17.74	17.73
75%	20.30	20.42
80%	23.60	23.71
85%	27.92	27.94
90%	33.84	33.92
95%	44.46	44.13
100%	143.37	Infinity

Assumption: Assumption for 20% VSI Xtendimax · 1 **Cell: B16**



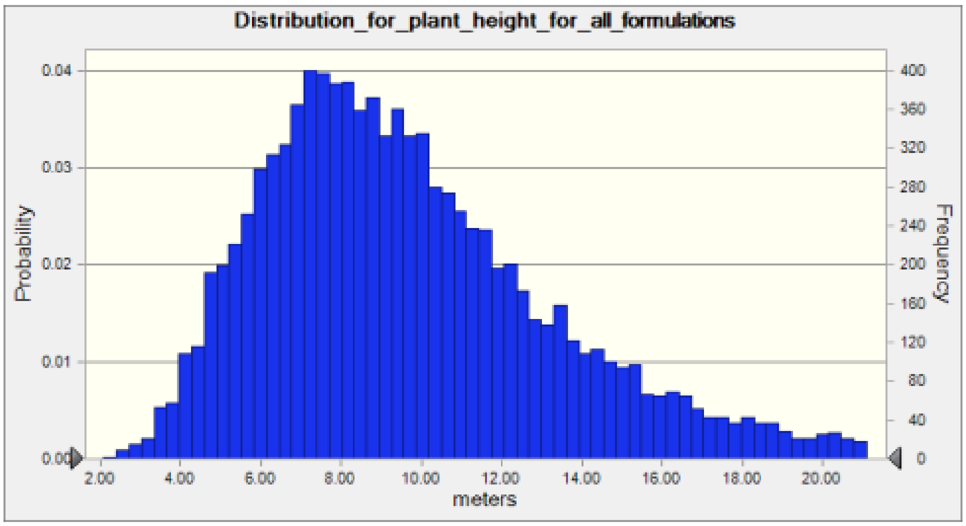
Assumption: Assumption for 20% VSI Xtendimax · 1 (cont'd) **Cell: B16**

Percentiles:	Assumption values	Distribution
0%	0.00	0.00
5%	0.78	0.74
10%	1.60	1.51
15%	2.44	2.33
20%	3.35	3.20
25%	4.25	4.12
30%	5.26	5.11
35%	6.32	6.18
40%	7.38	7.32
45%	8.65	8.57
50%	9.99	9.94
55%	11.52	11.45
60%	13.25	13.14
65%	15.11	15.05
70%	17.39	17.26
75%	20.25	19.88
80%	23.64	23.08
85%	27.97	27.20
90%	33.58	33.01
95%	43.52	42.95
100%	154.26	Infinity

Worksheet B2. Crystal Ball Report Forecasts. Percentiles Provided From Sampling of the Assumed Distribution

Forecast: Distribution_for_plant_height_for_all_formulations

Summary:
Entire range is from 2.10 to 37.30
Base case is 0.00
After 10,000 trials, the std. error of the mean is 0.04



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	9.83
Median	9.09
Mode	---
Standard Deviation	4.01
Variance	16.11
Skewness	1.31
Kurtosis	5.88
Coeff. of Variation	0.4084
Minimum	2.10
Maximum	37.30
Range Width	35.20
Mean Std. Error	0.04

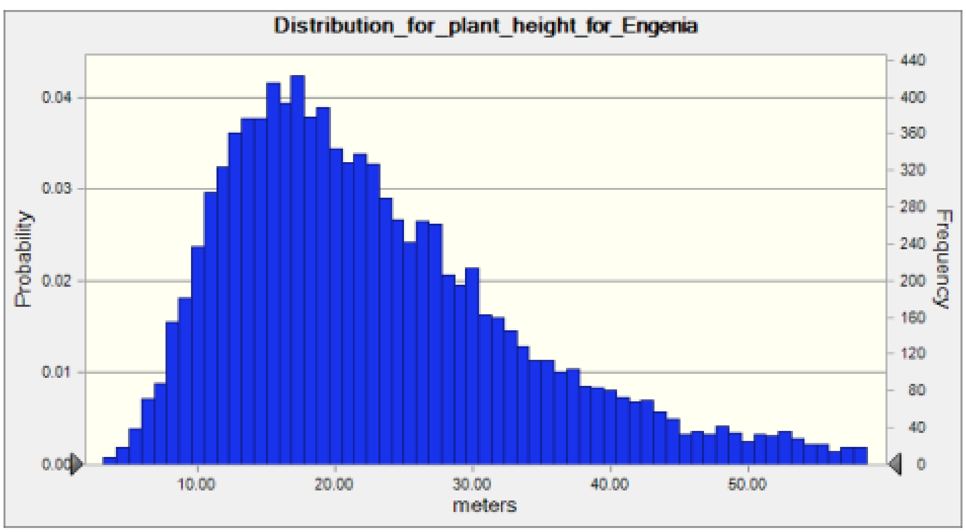
Forecast: Distribution_for_plant_height_for_all_formulations (cont'd)

Percentiles:	Forecast values
0%	2.10

5%	4.79
10%	5.53
15%	6.11
20%	6.60
25%	7.05
30%	7.43
35%	7.82
40%	8.22
45%	8.65
50%	9.09
55%	9.53
60%	9.99
65%	10.52
70%	11.11
75%	11.76
80%	12.57
85%	13.62
90%	15.06
95%	17.45
100%	37.30

Forecast: Distribution_for_plant_height_for_Engenia

Summary:
Entire range is from 3.21 to 137.75
Base case is 0.00
After 10,000 trials, the std. error of the mean is 0.12



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	23.57

Median	20.78
Mode	---
Standard Deviation	12.47
Variance	155.58
Skewness	1.68
Kurtosis	7.96
Coeff. of Variation	0.5293
Minimum	3.21
Maximum	137.75
Range Width	134.55
Mean Std. Error	0.12

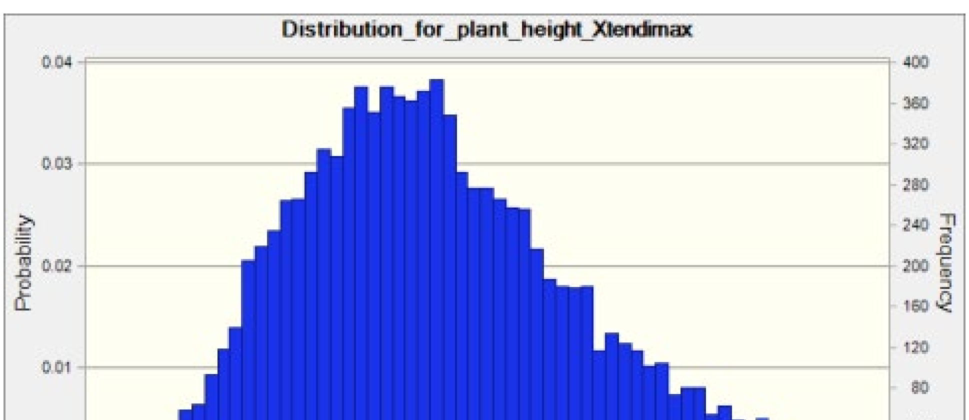
Forecast: Distribution_for_plant_height_for_Engenia (cont'd)

Percentiles:	Forecast values
0%	3.21
5%	9.29
10%	11.09
15%	12.50
20%	13.72
25%	14.88
30%	16.01
35%	17.15
40%	18.29
45%	19.48
50%	20.78
55%	22.15
60%	23.61
65%	25.24
70%	26.99
75%	29.10
80%	31.50
85%	34.85
90%	39.60
95%	47.89
100%	137.75

Forecast: Distribution_for_plant_height_Xtendimax

Summary:

Entire range is from 1.39 to 13.57
Base case is 0.00
After 10,000 trials, the std. error of the mean is 0.01



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	4.74
Median	4.53
Mode	---
Standard Deviation	1.50
Variance	2.24
Skewness	0.9539
Kurtosis	4.65
Coeff. of Variation	0.3159
Minimum	1.39
Maximum	13.57
Range Width	12.18
Mean Std. Error	0.01

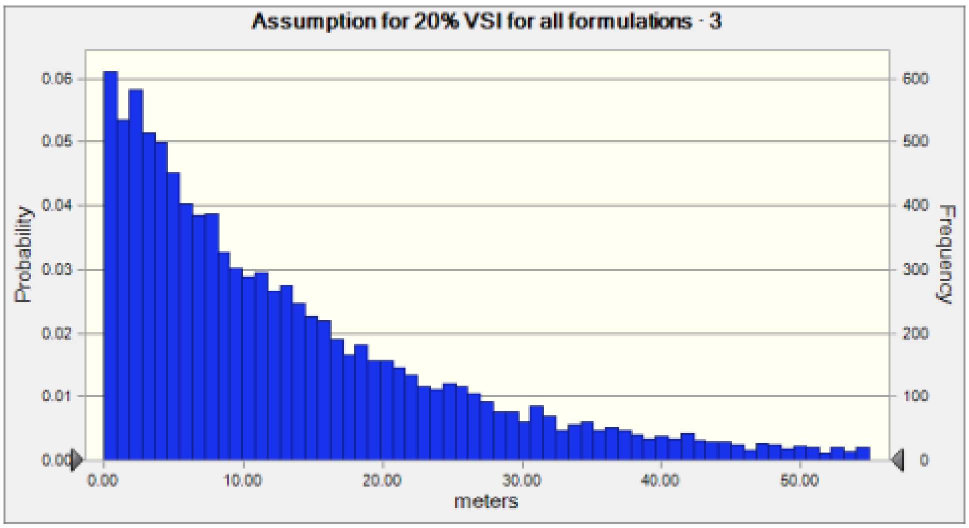
Forecast: Distribution_for_plant_height_Xtendimax (cont'd)

Percentiles:	Forecast values
0%	1.39
5%	2.71
10%	3.02
15%	3.26
20%	3.48
25%	3.68
30%	3.86
35%	4.03
40%	4.20
45%	4.37
50%	4.53
55%	4.70
60%	4.88
65%	5.09
70%	5.32
75%	5.56
80%	5.86
85%	6.21
90%	6.71
95%	7.47

100%	13.57

Forecast: Assumption for 20% VSI for all formulations · 3

Summary:
Entire range is from 0.00 to 181.75
Base case is 0.00
After 10,000 trials, the std. error of the mean is 0.14



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	14.33
Median	9.91
Mode	---
Standard Deviation	14.48
Variance	209.69
Skewness	2.08
Kurtosis	10.04
Coeff. of Variation	1.01
Minimum	0.00
Maximum	181.75
Range Width	181.75
Mean Std. Error	0.14

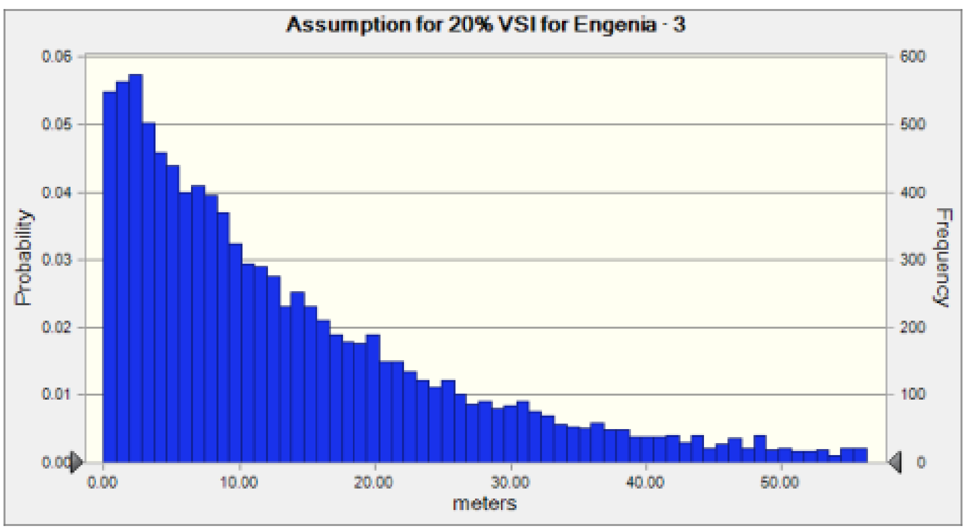
Forecast: Assumption for 20% VSI for all formulations · 3 (cont'd)

Percentiles:	Forecast values
0%	0.00
5%	0.74
10%	1.53

15%	2.32
20%	3.15
25%	4.12
30%	4.99
35%	6.10
40%	7.26
45%	8.47
50%	9.91
55%	11.46
60%	13.09
65%	14.92
70%	17.11
75%	19.80
80%	22.99
85%	26.97
90%	33.03
95%	43.51
100%	181.75

Forecast: Assumption for 20% VSI for Engenia · 3

Summary:
Entire range is from 0.00 to 143.37
Base case is 0.00
After 10,000 trials, the std. error of the mean is 0.15



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	14.79
Median	10.21
Mode	---

Standard Deviation	14.79
Variance	218.87
Skewness	2.04
Kurtosis	9.27
Coeff. of Variation	1.00
Minimum	0.00
Maximum	143.37
Range Width	143.37
Mean Std. Error	0.15

Forecast: Assumption for 20% VSI for Engenia · 3 (cont'd)

Percentiles:	Forecast values
0%	0.00
5%	0.83
10%	1.66
15%	2.47
20%	3.27
25%	4.31
30%	5.37
35%	6.49
40%	7.62
45%	8.81
50%	10.21
55%	11.77
60%	13.54
65%	15.43
70%	17.74
75%	20.30
80%	23.60
85%	27.92
90%	33.84
95%	44.46
100%	143.37

Forecast: Assumption for 20% VSI Xtendimax · 3

Summary:

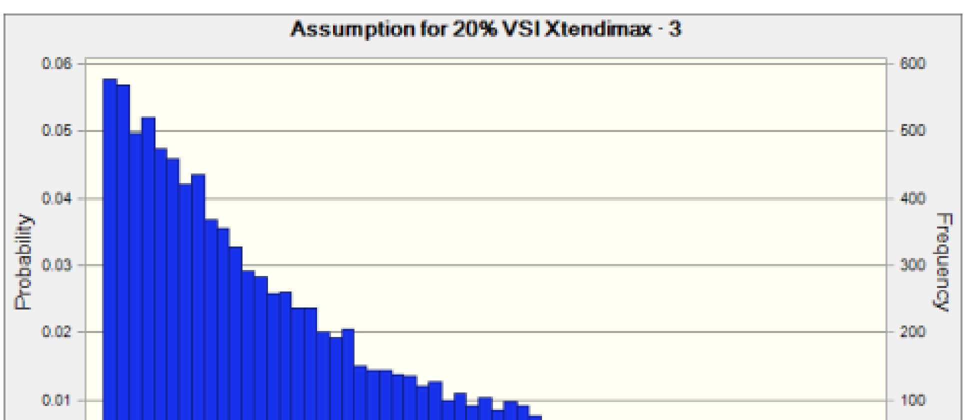
Certainty level is 100.00%

Certainty range is from -Infinity to 431.12

Entire range is from 0.00 to 154.26

Base case is 0.00

After 10,000 trials, the std. error of the mean is 0.15



Statistics:	Forecast values
Trials	10,000
Base Case	0.00
Mean	14.57
Median	9.99
Mode	---
Standard Deviation	14.54
Variance	211.44
Skewness	2.01
Kurtosis	9.22
Coeff. of Variation	0.9981
Minimum	0.00
Maximum	154.26
Range Width	154.26
Mean Std. Error	0.15

Forecast: Assumption for 20% VSI Xtendimax · 3 (cont'd)

Percentiles:	Forecast values
0%	0.00
5%	0.78
10%	1.60
15%	2.44
20%	3.35
25%	4.25
30%	5.26
35%	6.32
40%	7.38
45%	8.65
50%	9.99
55%	11.52
60%	13.25
65%	15.11
70%	17.39
75%	20.25
80%	23.64
85%	27.97
90%	33.58
95%	43.52

100%	154.26

Appendix D Effects Determinations Summary for all dicot and new animal species

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
513	Star cactus (Astrophytum asterias)	OFF	Hidalgo, TX, Starr, TX	Hidalgo, TX, Starr, TX	May Affect	No Effect	Not Applicable
568	Spring Creek bladderpod (Lesquerella perforata)	ON	Wilson, TN	Wilson, TN	May Affect	May Affect	No Effect
569	Zapata bladderpod (Lesquerella thamnophila)	OFF	Starr, TX	Starr, TX	May Affect	No Effect	Not Applicable
620	Northern wild monkshood (Aconitum noveboracense)	OFF	Allamakee, IA, Clayton, IA, Delaware, IA, Dubuque, IA, Hardin, IA, Jackson, IA, Grant, WI, Monroe, WI, Richland, WI, Sauk, WI, Vernon, WI	Allamakee, IA, Clayton, IA, Delaware, IA, Dubuque, IA, Hardin, IA, Jackson, IA, Grant, WI, Monroe, WI, Richland, WI, Sauk, WI, Vernon, WI	May Affect	No Effect	Not Applicable
624	South Texas ambrosia (Ambrosia cheiranthifolia)	OFF	Cameron, TX, Jim Wells, TX, Kleberg, TX, Nueces, TX	Cameron, TX, Jim Wells, TX, Kleberg, TX, Nueces, TX	May Affect	No Effect	Not Applicable
627	Tobusch fishhook cactus (Sclerocactus brevihamatus ssp. tobuschii)	OFF	Medina, TX	Medina, TX	May Affect	No Effect	Not Applicable
628	Price's potato-bean (Apios priceana)	OFF	Calloway, KY	Calloway, KY	May Affect	No Effect	Not Applicable
630	Braun's rock-cress (Arabis perstellata)	OFF	Henry, KY, Rutherford, TN, Wilson, TN	Henry, KY, Rutherford, TN, Wilson, TN	May Affect	No Effect	Not Applicable
636	Mead's milkweed (Asclepias meadii)	OFF	Ford, IL, **Iroquois, IL***, Will, IL, Anderson, KS, Barton,	Ford, IL, **Iroquois, IL***, Will, IL, Anderson, KS, Barton,	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
			MO, Harrison, MO, Johnson, MO, Pettis, MO, Vernon, MO, Columbia, WI, Dane, WI, Grant, WI, Green, WI	MO, Harrison, MO, Johnson, MO, Pettis, MO, Vernon, MO, Columbia, WI, Dane, WI, Grant, WI, Green, WI			
651	Texas poppy-mallow (Callirhoe scabriuscula)	OFF	Coke, TX, Mitchell, TX, Runnels, TX	Coke, TX, Mitchell, TX, Runnels, TX	May Affect	No Effect	Not Applicable
655	Small-anthered bittercress (Cardamine micranthera)	OFF	Forsyth, NC, Stokes, NC	Forsyth, NC, Stokes, NC	May Affect	No Effect	Not Applicable
677	Cumberland rosemary (Conradina verticillata)	OFF	White, TN	White, TN	May Affect	No Effect	Not Applicable
682	Lee pincushion cactus (Coryphantha sneedii var. leei)	OFF	Eddy, NM	Eddy, NM	May Affect	No Effect	Not Applicable
683	Sneed pincushion cactus (Coryphantha sneedii var. sneedii)	OFF	Do\xc3\xb1a Ana, NM, El Paso, TX	Do\xc3\xb1a Ana, NM, El Paso, TX	May Affect	No Effect	Not Applicable
702	Black lace cactus (Echinocereus reichenbachii var. albertii)	OFF	Jim Wells, TX, Kleberg, TX, Refugio, TX	Jim Wells, TX, Kleberg, TX, Refugio, TX	May Affect	No Effect	Not Applicable
709	Gypsum wild-buckwheat (Eriogonum gypsophilum)	OFF	Eddy, NM	Eddy, NM	May Affect	No Effect	Not Applicable
716	No common name (Geocarpon minimum)	OFF	Henry, MO, Jasper, MO	Henry, MO, Jasper, MO	May Affect	No Effect	Not Applicable
734	Dwarf-flowered heartleaf (Hexastylis naniflora)	OFF	Catawba, NC, Cleveland, NC, Iredell, NC, Lincoln, NC	Catawba, NC, Cleveland, NC, Iredell, NC, Lincoln, NC	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
739	Slender rush-pea (Hoffmannseggia tenella)	OFF	Kleberg, TX, Nueces, TX	Kleberg, TX, Nueces, TX	May Affect	No Effect	Not Applicable
750	Lyrate bladderpod (Lesquerella lyrata)	OFF	**Colbert, AL*, Franklin, AL*, Lawrence, AL***	**Colbert, AL*, Franklin, AL*, Lawrence, AL***	May Affect	No Effect	Not Applicable
763	Walker's manioc (Manihot walkerae)	OFF	Hidalgo, TX	Hidalgo, TX	May Affect	No Effect	Not Applicable
764	Mohr's Barbara's buttons (Marshallia mohrii)	OFF	**Calhoun, AL*,** Cherokee, AL	**Calhoun, AL*,** Cherokee, AL	May Affect	No Effect	Not Applicable
789	Papery whitlow-wort (Paronychia chartacea)	OFF	Jackson, FL	Jackson, FL	May Affect	No Effect	Not Applicable
818	Bunched arrowhead (Sagittaria fasciculata)	OFF	Henderson, NC	Henderson, NC	May Affect	No Effect	Not Applicable
819	Green pitcher-plant (Sarracenia oreophila)	OFF	Cherokee, AL, DeKalb, AL, Etowah, AL, **Jackson, AL*, Marshall, AL***	Cherokee, AL, DeKalb, AL, Etowah, AL, **Jackson, AL*, Marshall, AL***	May Affect	No Effect	Not Applicable
831	Fringed campion (Silene polypetala)	OFF	Jackson, FL	Jackson, FL	May Affect	No Effect	Not Applicable
835	Short's goldenrod (Solidago shortii)	OFF	Harrison, IN, Fleming, KY, Harrison, KY, Meade, KY	Harrison, IN, Fleming, KY, Harrison, KY, Meade, KY	May Affect	No Effect	Not Applicable
836	Gentian pinkroot (Spigelia gentianoides)	OFF	Calhoun, FL, Jackson, FL, Washington, FL	Calhoun, FL, Jackson, FL, Washington, FL	May Affect	No Effect	Not Applicable
843	Texas snowbells (Styrax texanus)	OFF	Uvalde, TX	Uvalde, TX	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
852	Cooley's meadowrue (Thalictrum cooleyi)	OFF	Mitchell, GA, Worth, GA, Brunswick, NC, Columbus, NC, Onslow, NC, Pender, NC	Mitchell, GA, Worth, GA, Brunswick, NC, Columbus, NC, Onslow, NC, Pender, NC	May Affect	No Effect	Not Applicable
872	Large-fruited sand-verbena (Abronia macrocarpa)	OFF	Robertson, TX	Robertson, TX	May Affect	No Effect	Not Applicable
875	Sensitive joint-vetch (Aeschynomene virginica)	OFF	**Salem, NJ*,** Beaufort, NC, Craven, NC, Hyde, NC, Lenoir, NC	**Salem, NJ*,** Beaufort, NC, Craven, NC, Hyde, NC, Lenoir, NC	May Affect	No Effect	Not Applicable
891	Decurrent false aster (Boltonia decurrens)	OFF	Bureau, IL, Cass, IL, Fulton, IL, Greene, IL, Jersey, IL, LaSalle, IL, Madison, IL, Marshall, IL, Mason, IL, Morgan, IL, Peoria, IL, Pike, IL, **Randolph, IL***, St. Clair, IL, Schuyler, IL, Scott, IL, Tazewell, IL, Woodford, IL, Cape Girardeau, MO, Dunklin, MO, Lincoln, MO, Mississippi, MO, Pike, MO, St. Charles, MO	Bureau, IL, Cass, IL, Fulton, IL, Greene, IL, Jersey, IL, LaSalle, IL, Madison, IL, Marshall, IL, Mason, IL, Morgan, IL, Peoria, IL, Pike, IL, **Randolph, IL***, St. Clair, IL, Schuyler, IL, Scott, IL, Tazewell, IL, Woodford, IL, Cape Girardeau, MO, Dunklin, MO, Lincoln, MO, Mississippi, MO, Pike, MO, St. Charles, MO	May Affect	No Effect	Not Applicable
905	Pitcher's thistle (Cirsium pitcheri)	OFF	**Brown, WI***	**Brown, WI***	May Affect	No Effect	Not Applicable
920	Leafy prairie-clover (Dalea foliosa)	OFF	LaSalle, IL, Will, IL	LaSalle, IL, Will, IL	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
945	Schweinitz's sunflower (Helianthus schweinitzii)	OFF	Anson, NC, Davidson, NC, Randolph, NC, Rowan, NC, Stanly, NC, Surry, NC, Union, NC	Anson, NC, Davidson, NC, Randolph, NC, Rowan, NC, Stanly, NC, Surry, NC, Union, NC	May Affect	No Effect	Not Applicable
957	Prairie bush-clover (Lespedeza leptostachya)	OFF	Cass, IL, Champaign, IL, Fayette, IL, Jo Daviess, IL, Lee, IL, McHenry, IL, Ogle, IL, Winnebago, IL, Brown, MN, Cottonwood, MN, Dakota, MN, Dodge, MN, Goodhue, MN, Jackson, MN, Martin, MN, Mower, MN, Nobles, MN, Olmsted, MN, Redwood, MN, Renville, MN, Rice, MN, Rock, MN, **Steele, MN***, Dane, WI, Grant, WI, Green, WI, Pierce, WI, Rock, WI, Sauk, WI	Cass, IL, Champaign, IL, Fayette, IL, Jo Daviess, IL, Lee, IL, McHenry, IL, Ogle, IL, Winnebago, IL, Brown, MN, Cottonwood, MN, Dakota, MN, Dodge, MN, Goodhue, MN, Jackson, MN, Martin, MN, Mower, MN, Nobles, MN, Olmsted, MN, Redwood, MN, Renville, MN, Rice, MN, Rock, MN, **Steele, MN***, Dane, WI, Grant, WI, Green, WI, Pierce, WI, Rock, WI, Sauk, WI	May Affect	No Effect	Not Applicable
959	Heller's blazingstar (Liatris helleri)	OFF	Burke, NC	Burke, NC	May Affect	No Effect	Not Applicable
960	Pondberry (Lindera melissifolia)	OFF	Bolivar, MS, Coahoma, MS, Leflore, MS, Sunflower,	Bolivar, MS, Sunflower, MS, Sampson, NC, Clay, AR,	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
			MS, Washington, MS, Sampson, NC, Clay, AR, Craighead, AR, Crittenden, AR, Cross, AR, Jackson, AR, Poinsett, AR, Prairie, AR, Woodruff, AR	Craighead, AR, Crittenden, AR, Cross, AR, Jackson, AR, Poinsett, AR, Prairie, AR, Woodruff, AR			
967	Rough-leaved loosestrife (Lysimachia asperulaefolia)	OFF	Beaufort, NC, Bladen, NC, Columbus, NC, Craven, NC, Cumberland, NC, Harnett, NC, Darlington, SC	Beaufort, NC, Bladen, NC, Columbus, NC, Craven, NC, Cumberland, NC, Harnett, NC, Darlington, SC	May Affect	No Effect	Not Applicable
976	Canby's dropwort (Oxypolis canbyi)	OFF	Florence, SC, Horry, SC, Orangeburg, SC	Florence, SC, Horry, SC, Orangeburg, SC	May Affect	No Effect	Not Applicable
977	Fassett's locoweed (Oxytropis campestris var. chartacea)	OFF	Portage, WI, Waushara, WI	Portage, WI, Waushara, WI	May Affect	No Effect	Not Applicable
978	Blowout penstemon (Penstemon haydenii)	OFF	Custer, NE, Lincoln, NE	Custer, NE, Lincoln, NE	May Affect	No Effect	Not Applicable
982	Godfrey's butterwort (Pinguicula ionantha)	OFF	Calhoun, FL	Calhoun, FL	May Affect	No Effect	Not Applicable
991	Harperella (Ptilimnium nodosum)	OFF	Dooly, GA	Dooly, GA	May Affect	No Effect	Not Applicable
992	Michaux's sumac (Rhus michauxii)	OFF	Cumberland, NC, Johnston, NC, Nash, NC, Robeson, NC, Union,	Cumberland, NC, Johnston, NC, Nash, NC, Robeson, NC, Union,	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
			NC, Wilson, NC	NC, Wilson, NC			
994	Alabama canebrake pitcher-plant (Sarracenia rubra ssp. alabamensis)	OFF	**Autauga, AL*, Chilton, AL*, Elmore, AL***	**Autauga, AL*, Chilton, AL*, Elmore, AL***	May Affect	No Effect	Not Applicable
996	American chaffseed (Schwalbea americana)	OFF	**Burlington, NJ*, Ocean, NJ***, Florence, SC, Horry, SC	**Burlington, NJ*, Ocean, NJ***, Florence, SC, Horry, SC	May Affect	No Effect	Not Applicable
1003	Houghton's goldenrod (Solidago houghtonii)	OFF	Genesee, NY	Genesee, NY	May Affect	No Effect	Not Applicable
1019	Seabeach amaranth (Amaranthus pumilus)	OFF	**Sussex, DE*, Monmouth, NJ***, Hyde, NC, Horry, SC	**Sussex, DE*, Monmouth, NJ***, Hyde, NC, Horry, SC	May Affect	No Effect	Not Applicable
1036	Ruth's golden aster (Pityopsis ruthii)	OFF	Polk, TN	Polk, TN	May Affect	No Effect	Not Applicable
1041	Running buffalo clover (Trifolium stoloniferum)	OFF	Dunklin, MO	Dunklin, MO	May Affect	No Effect	Not Applicable
1045	Texas prairie dawn-flower (Hymenoxys texana)	OFF	Fort Bend, TX	Fort Bend, TX	May Affect	No Effect	Not Applicable
1048	Alabama leather flower (Clematis socialis)	OFF	Cherokee, AL, Etowah, AL, Floyd, GA	Cherokee, AL, Etowah, AL, Floyd, GA	May Affect	No Effect	Not Applicable
1058	Mountain golden heather (Hudsonia montana)	OFF	Burke, NC, McDowell, NC	Burke, NC, McDowell, NC	May Affect	No Effect	Not Applicable
1059	Lakeside daisy (Hymenoxys herbacea)	OFF	Clinton, IL, Tazewell, IL, Will, IL, Erie, OH, Ottawa, OH	Clinton, IL, Tazewell, IL, Will, IL, Erie, OH, Ottawa, OH	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
1064	Kral's water-plantain (Sagittaria secundifolia)	OFF	DeKalb, AL	DeKalb, AL	May Affect	No Effect	Not Applicable
1077	Texas ayenia (Ayenia limitaris)	OFF	Cameron, TX, Hidalgo, TX, Willacy, TX	Cameron, TX, Hidalgo, TX, Willacy, TX	May Affect	No Effect	Not Applicable
1087	Guthrie's (=Pyne's) ground-plum (Astragalus bibullatus)	OFF	Davidson, TN, Rutherford, TN	Davidson, TN, Rutherford, TN	May Affect	No Effect	Not Applicable
1096	Morefield's leather flower (Clematis morefieldii)	OFF	Jackson, AL, **Madison, AL***, Franklin, TN, Grundy, TN	Jackson, AL, **Madison, AL***, Franklin, TN, Grundy, TN	May Affect	No Effect	Not Applicable
1150	Leedy's roseroot (Rhodiola integrifolia ssp. leedyi)	OFF	Fillmore, MN, Olmsted, MN	Fillmore, MN, Olmsted, MN	May Affect	No Effect	Not Applicable
1191	Florida torreya (Torreya taxifolia)	OFF	Jackson, FL, Decatur, GA, Seminole, GA	Jackson, FL, Decatur, GA, Seminole, GA	May Affect	No Effect	Not Applicable
1209	Alabama streak-sorus fern (Thelypteris pilosa var. alabamensis)	OFF	**Winston, AL***	**Winston, AL***	May Affect	No Effect	Not Applicable
1678	Bracted twistflower (Streptanthus bracteatus)	OFF	Medina, TX, Uvalde, TX, Williamson, TX	Medina, TX, Uvalde, TX, Williamson, TX	May Affect	No Effect	Not Applicable
1710	Fleshy-fruit gladecress (Leavenworthia crassa)	OFF	**Cullman, AL*, Lawrence, AL*, Morgan, AL***	**Cullman, AL*, Lawrence, AL*, Morgan, AL***	May Affect	No Effect	Not Applicable
1831	Short's bladderpod (Physaria globosa)	OFF	Posey, IN, Maury, TN, Montgomery, TN	Posey, IN, Maury, TN, Montgomery, TN	May Affect	No Effect	Not Applicable
1881	Whorled Sunflower (Helianthus verticillatus)	OFF	Cherokee, AL, Floyd, GA, Chester, TN, McNairy, TN, Madison, TN	Cherokee, AL, Floyd, GA, Chester, TN, McNairy, TN, Madison, TN	May Affect	No Effect	Not Applicable

EntityID	Species	On/Off Field	Counties with overlap	Accounting for ECOS updates**	No change to Federal Action effects determinations	Infield omni-directional buffer of distance 57 feet change to Federal Action effects determinations	County prohibition of use change to Federal Action effects determinations
7167	Kentucky glade cress (Leavenworthia exigua laciniata)	OFF	Bullitt, KY, Jefferson, KY	Bullitt, KY, Jefferson, KY	May Affect	No Effect	Not Applicable
8392	Missouri bladderpod (Physaria filiformis)	OFF	Dade, MO, Lawrence, MO	Dade, MO, Lawrence, MO	May Affect	No Effect	Not Applicable

* Sub-county information available in this county **(Bold)**
** Dropped counties based on available spatial information provided documented in ECOS

Appendix E Determination for all Dicot and New Animal and Non-Monocot Species Critical Habitat Modification.

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
1	Indiana bat (Myotis sodalis)	PCE not specified - Critical habitat designations are either mines or caves.	No GIS file due to sensitivity - overlap is assumed	no	no	no	no	n/a
41	Alabama beach mouse (Peromyscus polionotus ammobates)	PCE includes: contiguous mosaic of early-late successional scrub vegetation and dune habitat; primary-secondary dunes dominated by sea oats; scrub dunes dominated by scrub oak; and, unobstructed habitat connections.	Baldwin, AL	no	no	yes	yes	omni-directional buffer of distance 57 feet
67	Whooping crane (Grus americana)	"All areas proposed in this rule would provide food, water, and other nutritional or physiological needs of the whooping crane during spring or fall migration.	Buffalo, NE, Kearney, NE, Phelps, NE	no	yes	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		Consumption of some cereal crops in adjacent croplands during migration period." Direct relatable resources to agricultural field possibly treated with 2,4-D choline.						
149	Southwestern willow flycatcher (Empidonax traillii extimus)	PCE includes riparian habitat along a dynamic river or lakeside in a natural or manmade successional environment (for nesting, foraging, migration, dispersal and shelter) comprised of trees and shrubs (include willow species, boxelder, tamarisk, etc.) and dense riparian shrub/tree thicket interspersed with small openings of	Graham, AZ	no	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		open water or marsh or shorter vegetation.						
194	San Marcos salamander (Eurycea nana)	PCE not specified - Critical habitat defined simply as Spring Lake and its outflow, the San Marcos River, downstream roughly 50 meters from the Spring Lake Dam (Texas).	Hays, TX	no	no	no	no	n/a
558	Pecos (=puzzle =paradox) sunflower (Helianthus paradoxus)	PCE include desert wetland or riparian habitat components that provide a low proportion of woody shrub or canopy cover, and other abiotic conditions.	Chaves, NM, Pecos, TX	yes	no	yes	yes	omni-directional buffer of distance 57 feet
569	Zapata bladderpod (Lesquerella thamnophila)	PCE not specified - typical habitat described as open cenzino shrub community that grades into an blackbrush	Starr, TX	yes	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		shrub community; these communities apparently dominate upland habitats on shallow soils near the Rio Grande.						
1030	Huachuca water-umbel (Lilaeopsis schaffneriana var. recurva)	PCE includes a temporally stable riparian plant community; relatively stable stream channel subject to periodic flooding that provides rejuvenation of the riparian plant community and produces open microsites for Lilaeopsis expansion.	Cochise, AZ	yes	no	yes	yes	omni-directional buffer of distance 57 feet
1710	Fleshy-fruit gladecress (Leavenworthia crassa)	PCE includes glade habitats (i.e, shallow-soiled, open areas with exposed limestone bedrock or gravel dominated by herbaceous vegetation) protected	Morgan, AL	yes	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		from invasive or weedy plants.						
1881	Whorled Sunflower (Helianthus verticillatus)	PCE includes: sites with no forest canopy, or where woody vegetation is present in sufficiently low densities to provide full or partial sunlight to the understory, and which support vegetation characteristic of moist prairie communities; as well as occupied sites in which a sufficient number of compatible mates are available to allow outcrossing and the production of viable achenes.	Cherokee, AL, McNairy, TN, Madison, TN	yes	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
3412	Dakota Skipper (Hesperia dacotae)	PCE includes: wet-mesic tallgrass or mixed grass prairie containing 5-25% tree/shrub cover; native grasses (inc. prairie dropseed or little bluestem) to provide food, and native forbs (inc. purple coneflower, bluebell bellflower, white prairie clover, upright prairie coneflower, etc.) to provide nectar and water during periods of flight; perennial grassland habitat for dispersal with limited or no barriers to dispersal (including <25% tree cover and no row crops).	Clay, MN, Polk, MN, Pope, MN	no	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
4910	Salt Creek Tiger beetle (Cicindela nevadica lincolniana)	PCE includes: exposed mudflats associated with saline wetlands or the exposed banks and islands of streams and seeps to support egg-laying and foraging requirements (specifically includes Salmo and Saltillo soil types); vegetated wetlands adjacent to core habitats that provide shade for subspecies thermoregulation, support a source of prey for adult and larval forms of the species, and protect core habitats.	Lancaster, NE, Saunders, NE	no	no	yes	yes	omni-directional buffer of distance 57 feet
7167	Kentucky glade cress (Leavenworthia exigua laciniata)	PCE includes: cedar glades and gladelike areas within the species' range that include full or nearly full sunlight and an	Bullitt, KY, Jefferson, KY	yes	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		undisturbed soil seed bank; vegetated land around glades and gladelike areas that extends up and down slope and ends at natural or manmade breaks.						
10147	Poweshiek skipperling (Oarisma poweshiek)	PCE includes: wet-mesic tallgrass or mixed grass prairie containing a predominance of native grasses and flowering forbs and 5-25% tree/shrub cover; prairie fen habitats containing a predominance of native grasses and flowering forbs - native grass species are to provide food and cover (species include prairie dropseed, little bluestem,	Clay, MN, Polk, MN	no	no	yes	yes	omni-directional buffer of distance 57 feet

Entity ID	Species Name	Notes on Relevant Primary Constituent Elements (PCE)	Counties	Non-monocot plant?	PCEs include Ag fields?	PCE's include Non-monocot plants	Mitigation required for "no modification"	Mitigation
		etc), and native forbs are to provide nectar and water during periods of flight (inc. purple coneflower, black-eyed Susan, smooth ox-eye, stiff tickseed, etc.); perennial grassland habitat for dispersal with limited or no barriers to dispersal (including <25% tree cover and no row crops).						

Appendix F. Incidents

As noted previously numerous incidents of damage to soybean and other crop and non-crop species were reported to EPA by States in 2017 and 2018. While very few formal submissions of the nature of the incidents have been provided to the Agency, virtually all reports associated the damage to plants to the dicamba GMO use. EPA has tabulated reported numbers of incidents by state for 2017 and 2018. In general, the greatest cluster of incidents are associated with soybean use in AR, MO, IL, MN (2017), and IN (2018) with far fewer reported in the deep south, upper Midwest, and eastern portions of the soybean and cotton growing areas. **Figure F.1** below presents a map that overlays the numbers of incidents by state for 2018 relative to the location of field trials conducted in 2017 and 2018 (yellow hash marks) discussed in this assessment. Overall it appears that most incidents appear to correlate with the states clustered along the middle Mississippi River valley. In addition, there is a correlation between where the field trials were being conducted and where the incidents are occurring, though the correlation is not strong.

There are several uncertainties with this analysis. The number of incidents may not accurately represent the extent of dicamba-related damage; incidents may be under- or over-reported. See discussion on "Incidents Alleging Crop Damage from Off-Target Movement of Dicamba" in the EPA's 2018 Over-the-Top Dicamba Products for Genetically Modified Cotton and Soybeans: Benefits and Impacts. It is also unclear how other factors such as variation in climate, topography (*e.g.,* inversion potential), water chemistry (e.g. water pH), and agricultural practices (e.g. water softening for hard water) influence these occurrences. However, the mapping of incidents is suggestive of a tendency for greater numbers of damaged acres of non-GMO soybean in the middle portion of the registered use area.

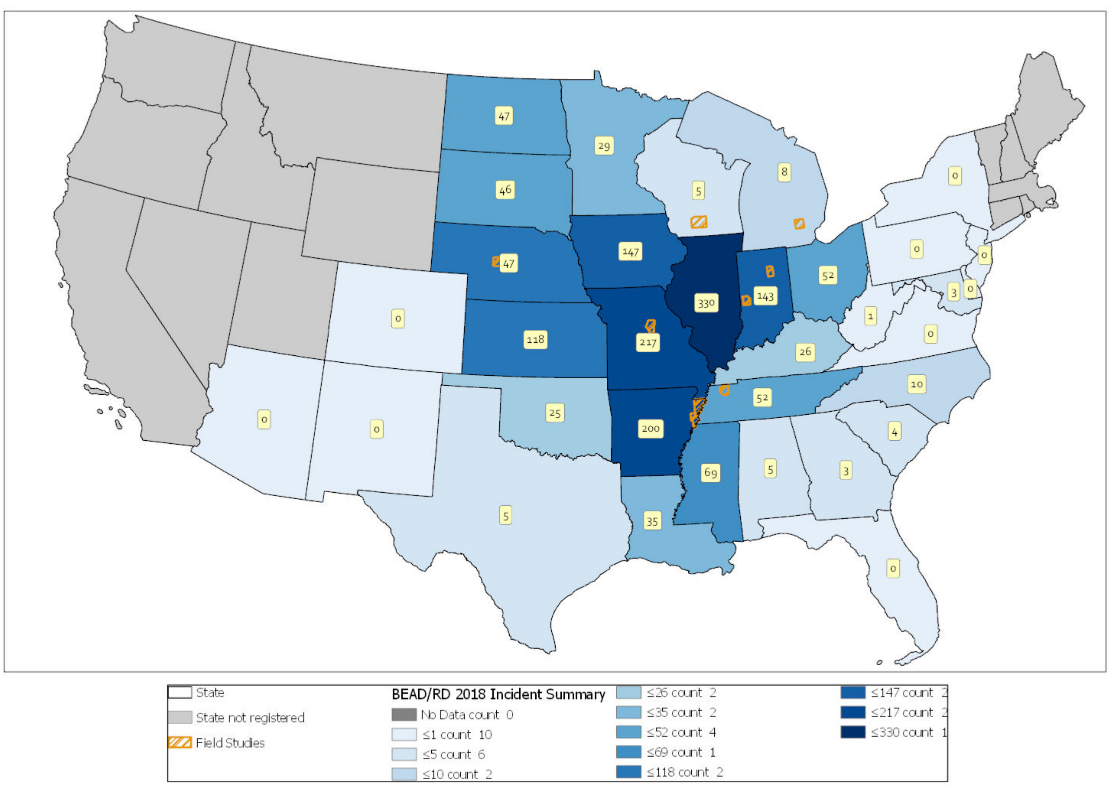


Figure F.1. Locations of 2018 Incident Data and Field Studies

Appendix G. Meeting Minutes for EPA Discussion with Dr. Norsworthy (10/4/2018)

On Thursday, Oct 4th, EPA members participated in a conference call with Dr. Norsworthy regarding the 2018 study to get clarification on the potentially confounding issues:

- **Issue One: Acetochlor tank mix and potential to adversely affect soybeans during the trials**

  With regards to the effects of the use of Warrant, Dr. Norsworthy indicated it was the registrant and grower, not Dr. Norsworthy, who prepared the tank mix to include Warrant. With regards to damage resulting from acetochlor, Dr. Norsworthy indicated that Warrant can be used as post-emergent application on soybeans and that there was no acetochlor damage to the Xtend soybeans, planted on the treated field, or the Roundup Ready soybeans, planted surrounding the treated field. Additionally, Dr. Norsworthy indicated that the damage resulting from acetochlor exposure is fundamentally different from that produced by dicamba and that the majority of weed scientists can differentiate between these types of damage. While dicamba damage results in a cupping of the leaves, acetochlor damage results in a crinkling of the leaf and a wavy appearance.

- **Issue Two: Acetochlor tank mixture could alter the volatile potential of dicamba in the study, negating Xtendimax with Vapor Grip performance**

  Dr. Norsworthy has investigated the effect of tank mixture partners and tank holding time as it relates to tank content pH. This was done to address any concern that conditions of the tank mixture could have altered the pH of the spray tank contents such that the buffering capacity of Xtendimax would be nullified and promote low pH shift, inducing enhanced dicamba volatility. Preliminary data show no effect on tank pH with Warrant as a tank mix partner, including tank mix holding time.

  Dr. Norsworthy indicated that he has also conducted trials under hoop tunnels investigating volatility of Xtendimax with (1) Roundup Powermax II and Warrant and (2) Roundup Powermax II and Warrant that had been sitting in a tank for 4 days (approximating the tank holding time encountered in the field study). Preliminary data indicates that there was no increase in volatility based on tank holding time.

  Dr. Norsworthy has committed to sharing these data with EPA.

  Issue Three: Plant damage scoring is alleged to be atypical compared to other field studies

  Dr. Norsworthy referred EPA to the two types of visual signs of injury methods used to score observations of injury during the field study. Both methods were employed side by side during the evaluation of transect. Both methods are in close agreement with respect to visual damage extent at each point along the transects.

  Issue Four: Tarped plants were insufficient to prevent spray drift damage, thereby overestimating the role of vapor drift in the study

Dr. Norsworthy emphasized that the use of the tarps was at the behest of the registrant sponsor and are not inconsistent with the method used in other field studies, including those conducted by the registrant.

Issue Five: The use of bucketed plants along transects to segregate damage from primary drift from secondary vapor drift was inappropriate due to the potential for cross contamination with adjacent un-bucketed plants.

Dr. Norsworthy indicated that plants within 6 inches of the outside of the buckets were removed in order to prevent cross contamination of the bucketed plants from plants impacted by primary and secondary drift.

Issue Six: The use of bucketed plants along transects to segregate damage from primary drift from secondary vapor drift unduly stressed the plants and resulted in questionable results attributed to vapor exposure.

Dr. Norsworthy indicated that buckets were in-place only for the duration of spray and for up to 30 minutes post application. He did state that visible plant stress occurred as a result of covering the plants with tarps and buckets. However, the plant damage from tarp/bucket effects was easily distinguishable from the damage resulting from dicamba exposure and the damage from tarps/buckets was no longer apparent 21 days after treatment. His presentation of visual signs of damage for bucketed plants was based on the extent of visual signs of damage consistent to the scoring of the types of damage attributable to dicamba exposure. Dr. Norsworthy also reiterated the similarity of the extent of damage with distance between bucketed and non-bucketed plants, suggesting a common level of exposure.

Issue 7: Irrigation confounds the transect data because the irrigation water can be transporting herbicide to the off-treatment field soybeans.

Dr. Norsworthy confirmed for EPA that no irrigation water originating from the treatment area was transported to the transect areas for the west, east and south transects of the field study. The only transect receiving irrigation water originating from the treated field was to the north. Visual plant damage along the North transect extended much further than the other transects; 40% visual damage extended to approximately 750 ft for the North transect, whereas for the South, East, and West transects, 40% visual injury was limited to 150 ft. Flood irrigation was employed at the site and irrigation water was applied approximately 7-10 days after the dicamba application. (Note for this reason, EPA has confined its evaluation of the field study to the west, east and south transects.) Discussions with Dr. Norsworthy indicated that off-site damage was most pronounced for soybean plants that had received runoff from the treated field and that the visual injury to plants Northeast and Northwest of the field, that did not receive runoff from irrigation water, was much lower than those that had received runoff water. As such, Dr. Norsworthy concluded that the visual injury along the North transect was the result of dicamba in the runoff from the irrigated field. Dr. Norsworthy also indicated that data from another site, where irrigation was not performed, but a significant rainfall event occurred within three days of application, produced similar off-field plant effects as seen in the north transect of Proctor, Arkansas field study.

- **Future availability of yield data**

EPA asked if yield data would be available soon for use in the analysis. Dr. Norsworthy indicated that the fields would not be harvested until the 3rd or 4th week of October.

- **Potential hypotheses to explain differences in the Arkansas data and other field trials from other areas**

  EPA inquired of Dr. Norsworthy his thoughts as to why the results from his trials were different than those observed in other areas of the country. Dr. Norsworthy indicated that he wasn't sure. Dr. Norsworthy indicated there could be issues relating to the proximity of the region to Crowley's Ridge and the frequency of inversions in the area, and that soil pHs were low in region relative to other areas of the country. In the end, Dr. Norsworthy indicated that there were a lot of complicating factors and that temperature, while it plays a major role in volatilization, was not the only factor.

  Referring back to the discussion of irrigation, Dr. Norsworthy also discussed the potential for irrigation to play a role. He opined that Midwest soils may have sufficient moisture and fertility characteristics as opposed to the South-central soils which are thinner in depth of topsoil and often require irrigation to maintain adequate soil moisture. He also opined that the presence of irrigation has the potential to enhance visual damage extent as the plants are actively growing, but may also limit the extent of damage to yield because the plants have resources to affect recovery from damage.

Appendix H. Discussion of additional factors influencing off-site vapor drift

H.1 Temperature

Temperature influences the vaporization rate of a pesticide mainly through its effect on the vapor pressure of the pesticide. Vapor pressures of pesticides typically follow a reciprocal-temperature relationship given by the Antoine equation[4]

$$logVP = A - \frac{B}{T + C}$$

where VP is the vapor pressure, T is the temperature, and A, B, and C are constants specific to the chemical. From the equation, as the temperature increases, the value B/(T+C) decreases, and vapor pressure increases. As such, as the air temperature and soil temperature increase, so does the vapor pressure of dicamba and subsequently the vaporization rate. This is not to say that other environmental factors, such as wind speed, soil moisture, precipitation, and sorption to soil particles and plant surfaces, may not also play a role in enhancing or retarding vaporization, only that temperature is considered an important factor in evaluating the evaporation of dicamba. **Figure H.1** depicts the effect of temperature on the vapor pressure of dicamba[5]. Based on this curve, the volatility of dicamba begins to move away from a flat line and begins to increase at approximately 90°F. Current label language instructs users on practices to minimize spray drift by accounting for the effect of temperature on droplet size[6]. This current restriction is not intended to address volatile emissions of dicamba.

[4] Spencer, W. and Cliath, M. 1974. Vaporization of Chemicals. Environmental Dynamics of Pesticides, Rizwanul Haque and VH Freed, editors.
[5] Recreated from Abraham, W. Date Unknown. The Chemistry Behind Low-Volatility Dicamba. https://blog.americanchemistry.com/wp-content/uploads/2018/06/Dicamba_TheOtherDicambaStory.pdf
[6] Current label language for Xtendimax states "when making applications in low relative humidity or temperatures above 91^0 F set up equipment to larger droplets to compensate for evaporation."

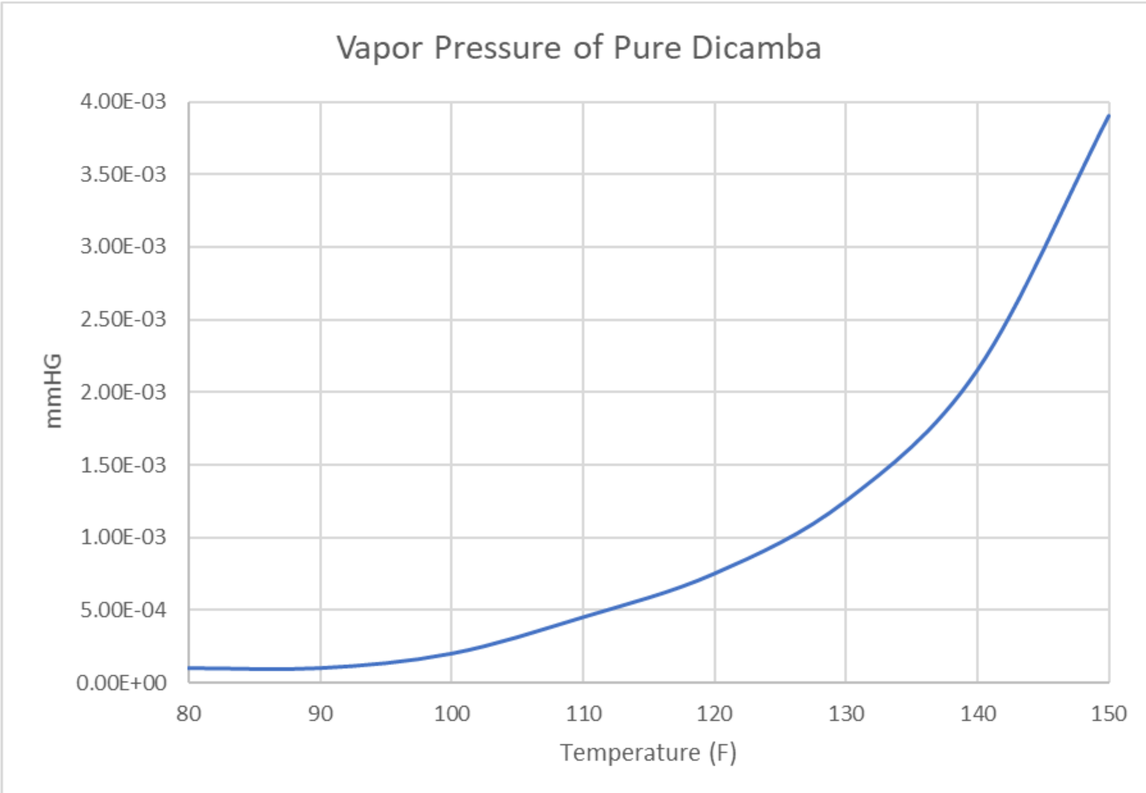


Figure H.1. Temperature Effects on the Vapor Pressure of Pure Dicamba

H.2 The role of pH and vapor drift

Considering the chemistry of dicamba and the VaporGrip technology, it is clear that pH also plays a role in the volatilization of dicamba from a treated field. Dicamba has a pKa of 1.87 and is governed by the typical acid-base equilibrium of a weak carboxylic acid. As the pH of a formulation shifts away from the pKa of dicamba and towards higher pH levels, more of dicamba is dissociated and only a very small fraction of dicamba is in the free acid form, which is the volatile form of dicamba. For a pH of 5.0, only 0.1% of the dicamba is in the free acid form. Most dicamba products are formulated as dicamba salts of organic amines. These salts when dissolved in water dissociate into dicamba anion and counterion which is invariably an organic ammonium cation. The dicamba anion can combine with any available proton (H+) in solution to form the volatile dicamba acid.[2]

The ability to maintain the pH above levels where dicamba acid forms is critical in controlling dicamba volatility potential from that formulation and any other additives added to the spray solution to be applied. The VaporGrip Technology (used in the Xtendimax formulation) uses a buffering agent to help maintain the pH of a solution to reduce the vapor pressure of dicamba and prevent the movement of dicamba from treated fields. **Figure H.2** provides a comparison of the vapor pressures of pure dicamba and that of dicamba in Xtendimax.[2]

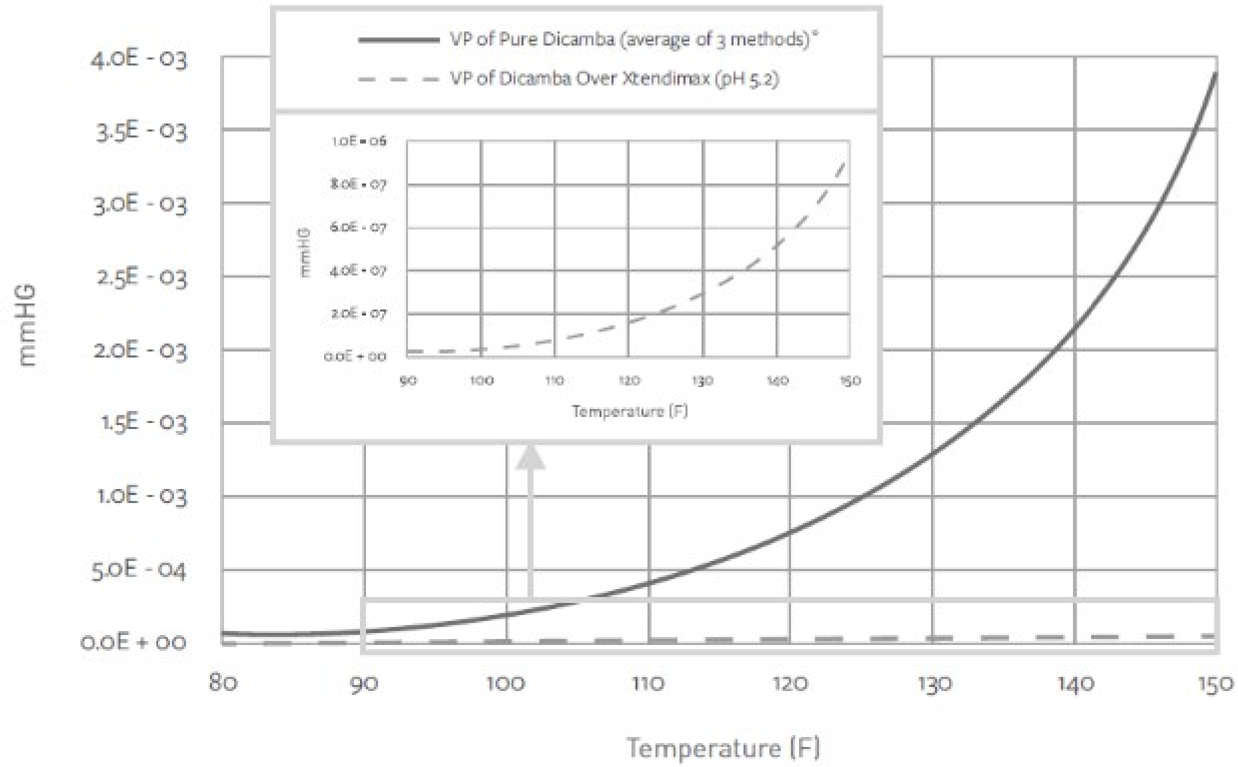


Figure H.2. Comparison of Vapor Pressures for Pure Dicamba and Xtendimax

However, several studies (discussed below) have been submitted to the Agency to indicate that the addition of glyphosate to dicamba products may be lowering the pH and increasing the volatility of dicamba.

H.2.2 Dupont Trials

Dupont conducted a number of trials in 2016 and 2017 evaluating the effects to volatility of adding glyphosate FeXapan (DuPont's dicamba product). In a set of humidome trials, different formulations of dicamba, applied alone, with different formulations of glyphosate, and with combinations of glyphosate plus other herbicides, were dispersed in water. Dicamba was applied at a rate of 1120 g ae/ha (1 lb ae/A), using different product formulations along with different formulations of glyphosate applied at 2240 g ae/ha (2 lb ae/A). The resulting water solutions were sprayed through a flat fan nozzle in a laboratory sprayer at a water spray volume of 93.5 L/ha onto soil spread evenly, 1-cm deep, in a 26 cm by 52 cm plastic tray. Trays containing herbicide-treated soil were immediately covered with plastic domes that contained an exit portal suitable for a glass tube filled with a polyurethane foam filter. Covered trays, containing herbicide-treated soil and glass tubes, were incubated in a growth chamber set at 35°C (95 °F) and 40% relative humidity with a 14-hr light cycle of 150 µmol/m2 of light for 24 hours. During the 24-hr incubation, air was pulled over the treated soil and through the polyurethane foam filter at a rate of 2 L/min. Dicamba was then extracted from the foam filters and was quantified via liquid chromatography/mass spectrometry/mass spectrometry (LC/MS/MS) analysis. Results of the trials are provided in **Table H.1**. Volatility appears to decrease from Banvel to Clarity to FeXapan, but then increases with the addition of different forms of glyphosate. Flux rates were estimated by the reviewer by dividing the mass in the filter by the area of the tray (26 cm by 52 cm) and the duration of the trial (24 hours). The 24-hour average flux rates for FeXapan with glyphosate are comparable to those estimated for the field volatility studies provided in **Figure 1** in **Section 4** above.

Table H.1. Comparison of the Volatility of Various Dicamba Products, With and Without Glyphosate

Herbicide products applied	Mass per filter (µg)	24-hour Average Flux (µg/m²-s)	Number of samples
Banvel	23.8 ± 4.2	2.04E-03	9
Clarity	0.42 ± 0.25	3.60E-05	18
FeXapan	0.04 ± 0.02	3.42E-06	18
FeXapan+Durango (DMA salt of glyphosate)	6.77 ± 1.67	5.80E-04	9
FeXapan+Honcho (IPA salt of glyphosate)	7.4 ± 2.36	6.33E-04	9
FeXapan+RoundUp Powermax (K salt of glyphosate)	4.28 ± 1.03	3.66E-04	18
M-1768 (premix dicamba+glyphosate+Vaporgrip)	0.19 ± 1.11	1.63E-05	9

In a second set of humidome trials, the volatility of XtendiMax with VaporGrip (Dicamba DGA) and tank mixtures with Round Up PowerMax (potassium salt glyphosate), Durango DMA (dimethylamine salt glyphosate), Intact Xtra, K_2PO_4, and ammonium sulfate (AMS) were evaluated. Applications of dicamba were made at 560 g ae/ha (0.5 lb ae/A). Volatility chamber experiments (0.9 cm thick acrylic with outside dimensions of 51 x 26 x 39 cm in length, width and height, respectively) were used, where the temperature and relative humidity were controlled for up to 96 h. Air sampling tubes were connected to 0.64 cm diameter tubing placed through the volatility chamber cover. A centralized source supplied a vacuum calibrated to 1 L/min with air flow valves. Sampling tubes were changed out at 24, 48, 72 and 96 h after herbicide application and the acid of dicamba were quantified via LC/MS/MS. **Figure H.3** presents some of the results. More dicamba is released as the pH decreases. It also appears that when Intact is used, some of the impact of glyphosate on reducing pH is suppressed. Also, as discussed earlier, as the pH drops below 5, the amount of dicamba that is released increases significantly (3-10x). It should be noted that the addition of AMS to Xtendimax (the second bar from the left in **Figure H.3**) in a tank mix is prohibited on the label.

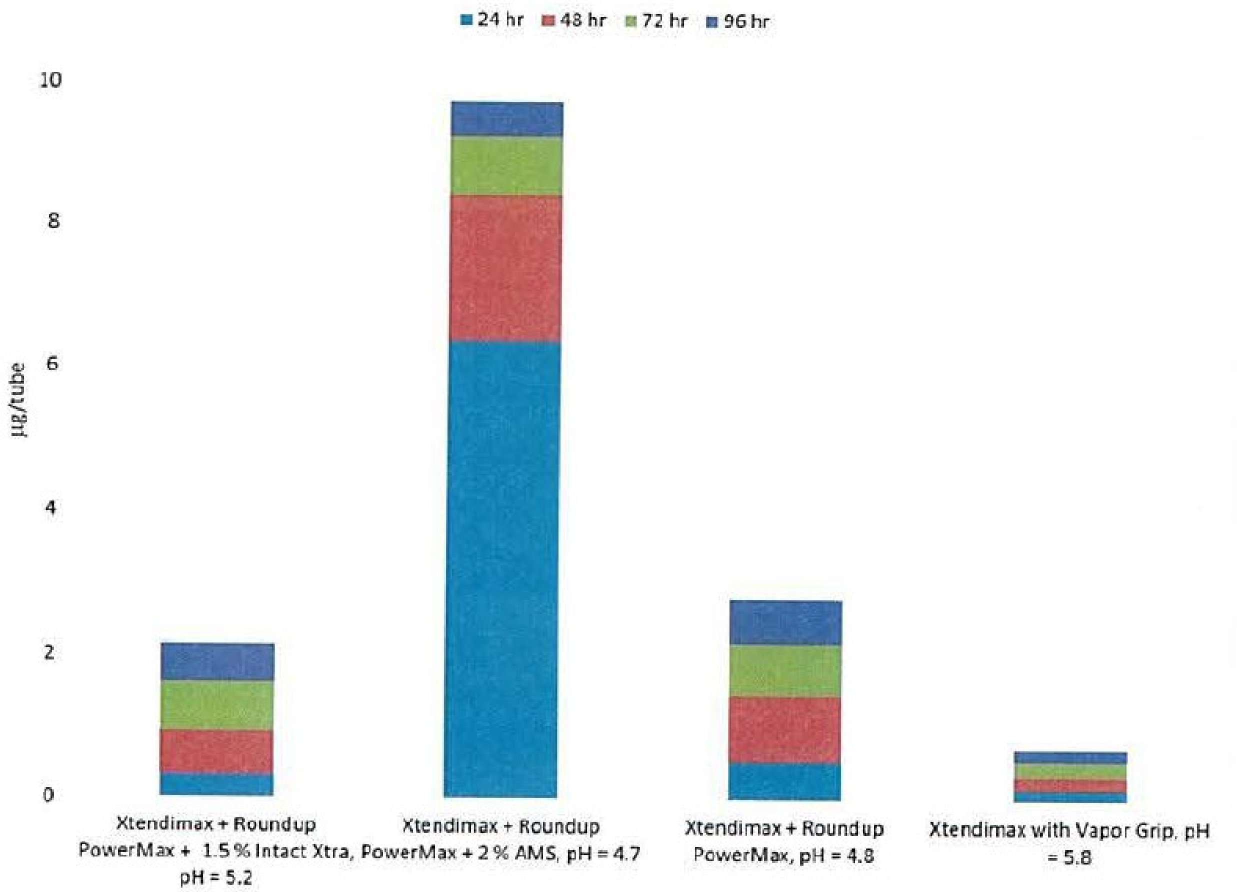


Figure H.3. Comparison of Volatility and pH for Various Xtendimax Mixtures

H.2.3 Norsworthy Trials

In the summer of 2018, Dr. Norsworthy from the University of Arkansas conducted low tunnel tests to assess the relative volatility of dicamba products in the field. Soil placed in trays was treated with various dicamba products at 2 lbs ae/A (4x the maximum label rate), with and without glyphosate added to the tank mix. Treated soil trays were then inserted into a tunnel which enclosed two rows of non-dicamba tolerant soybean plants. Soybean plants were in the V2 to V6 growth stage. After 48 hours, the tunnels and treated soil trays were removed and the soybean plants were monitored for visual injury 26 days after application. **Figure H.4** depicts the results. Visual injury increases for Engenia when glyphosate (Roundup Powermax) is added to the product mixture. A similar analysis for how the visual injury changes for Xtendimax with and without glyphosate was done in September 2018, but the results are not available. Additionally, as part of the study the pH of the solutions was also tested before and after application. The results are provided in **Figure H.5**. From the figure, the pH of Xtendimax alone is roughly 5.5 before and after application. But with the addition of glyphosate, the pH drops to around 5, allowing for more of the dicamba free acid to form.

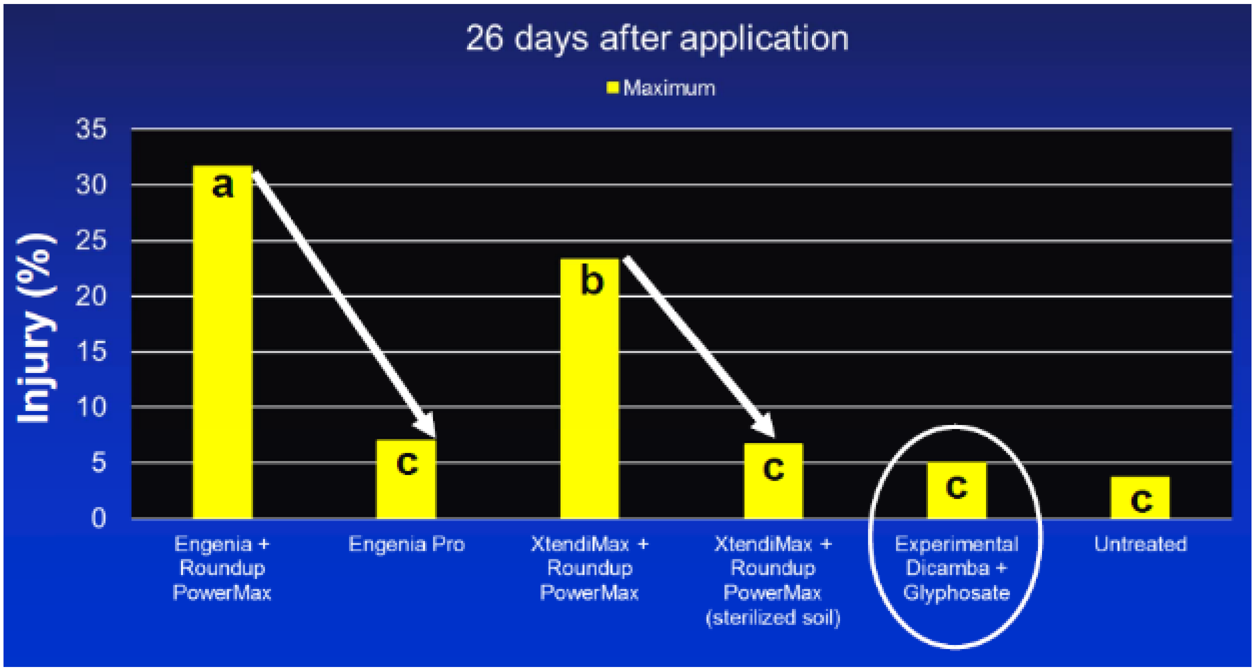


Figure H.4. Visual Injury of Soybeans to Various Dicamba Mixtures

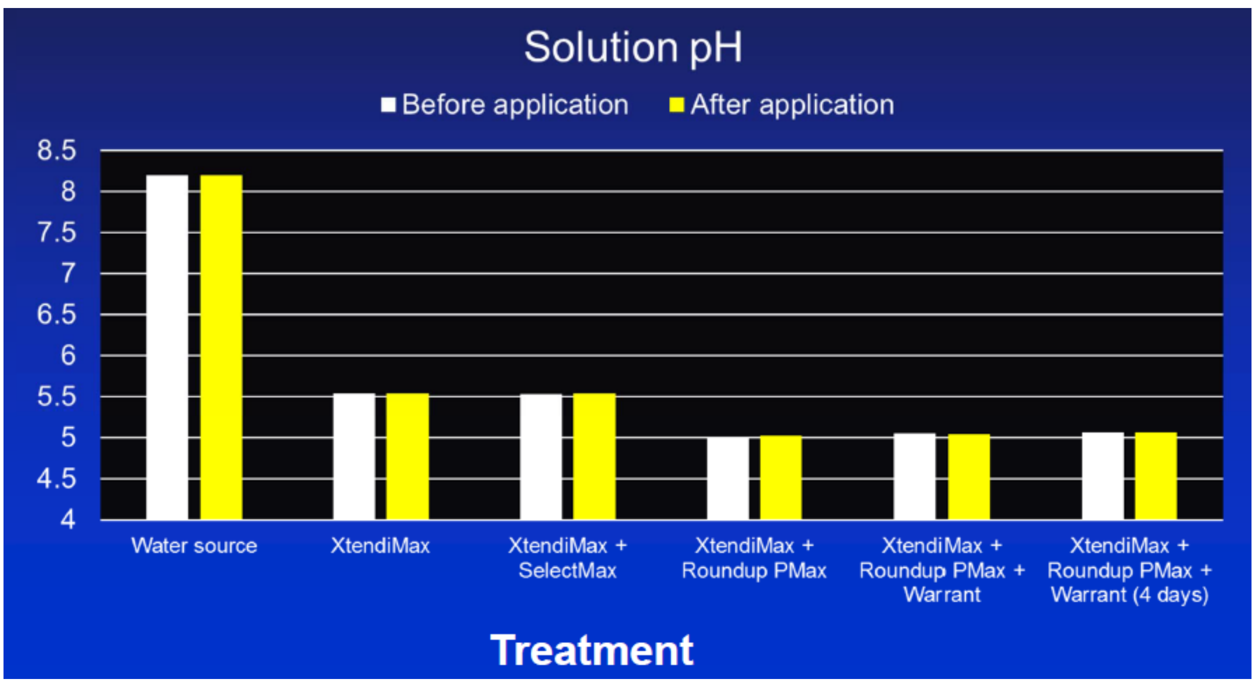


Figure H.5. Impact of Roundup Addition to Xtendimax on pH

Lastly, referring to **Figure 5** (**Section 4.1.1**), the total emissions from a field treated with Xtendimax (the top two bars in the figure) are lower than all of those where glyphosate (Roundup) is added to the tank mix.

H.3 Summary and Data Needs (Temperature and pH)

In summary, volatility is an exposure component of most field study plant responses, as seen in the large and small field trials. Temperature, in theory, influences the vapor pressure of dicamba and therefore volatility. Additionally, data evaluating the role of temperature while controlling other variables could inform potential mitigation practices. The pH of the tank mix solution has the potential to alter the extent of volatility as well, with decreasing pH resulting in increasing volatility. As a result, given the same environmental conditions, if the pH of the tank mixture drops below 5, increased volatility is likely to occur and plant responses to dicamba secondary drift are likely to extend over longer distances. Additional data examining the approved tank mix partners and how they impact the pH of the product would allow EPA to evaluate if this is occurring. Testing tank mix partners and including a series of waters designed to mimic the variety of water pH throughout the country, particularly in areas with the largest number of incidents, would inform this uncertainty.